Greening the Blue Revolution: How History Can Inform a Sustainable Aquaculture Movement

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by Turner Smith
Harvard Law School, Class of 2012
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Abstract

This Paper traces the history of aquaculture from ancient China until the present, highlighting the various degrees of, and reasons for, aquaculture's popularity at different points throughout history. The history of aquaculture demonstrates that the industry is largely a manifestation of concern over environmental and economic costs of the capture fishery industry; yet the current practice of aquaculture has begun to resemble the tortured past of wild-caught fish, with mono-culture fish farms causing serious environmental and economic problems for inland and coastal human and natural environments. Thus, this Paper argues that the history of the development of the aquaculture industry can serve as a cautionary tale as the industry moves forward, using the rubric of Garrett Hardin's The Tragedy of the Commons *to delineate the ways in which aquaculture succeeds and fails at achieving one of its fundamental purposes: to provide a sustainable method of protein provision to human society. This Paper posits that aquaculture, historically viewed as a substitute for dwindling wild fish stocks, a solution to the exploitation of a global commons, should itself also be viewed as a contributor to serious tragedies of the commons by both exploitation and by pollution. However, aquaculture has never been adequately regulated holistically as an instigator of environmental and economic problems. Thus, for the aquaculture industry to realize its full, impressive potential as an environmentally beneficial, economically sound, and domestically responsible method of protein production, it must draw lessons from its history to become a sustainable, "green" blue revolution.*

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How History Can Inform a Sustainable Aquaculture Movement

Turner Smith[1]

One great Point in the Conduct of Fish, is, to have them at command; another is, to have perpetual Recruits, to supply your stock as you draw it off. This is not to be done without a certain Order and Method, and with it, nothing is more practicable and easy.

-Roger North, 1713[2]

I. Introduction

The United States' aquaculture[3] industry "lies at a crossroads."[4] On the one hand, aquaculture holds promise to provide much-needed protein throughout the world, especially in developing countries, to ease stresses on degraded, over-fished aquatic and marine environments, and to close the growing trade gap in seafood products in the United States.[5] To this end, the

[1] Candidate for J.D., May 2012, Harvard Law School. I would like to thank Professor Wendy Jacobs and Professor Peter Barton Hutt of the Harvard Law School for sparking my interest in, and allowing me to further pursue, the subject of aquaculture. I am also very grateful to David Gerstle, Nancy Smith, and Walker Buckner.

[2] HON. ROGER NORTH, DISCOURSE OF FISH AND FISH PONDS (DONE BY A PERSON OF HONOUR), LONDON, PRINTED FOR E. CURLL 1 (1913).

[3] This Paper generally adopts a definition of aquaculture used by the National Oceanic and Atmospheric Administration ("NOAA"):

> the breeding, rearing, and harvesting of plants and animals in all types of water environments including ponds, rivers, lakes, and the ocean.

National Oceanic and Atmospheric Administration, What is Aquaculture?, http://www.nmfs.noaa.gov/aquaculture/what_is_aquaculture.html (last visited March 11, 2012). However, the historical narrative in this Paper necessarily discusses aquaculture as the practice of only rearing and harvesting, as breeding techniques emerged relatively recently in aquaculture's millennia of history. This Paper does not distinguish between aquaculture and mariculture, the latter of which is often used in industry literature to refer solely to sea farming, or aquaculture in salt or brackish waters, typically the ocean. *See* Thomas Kane, *University of Miami Sea Grant Program on Ocean Law: Aquaculture and the Law*, 2 SEA GRANT TECHNICAL BULL. 1 (1970).

[4] THE WORLD BANK, CHANGING THE FACE OF THE WATERS: THE PROMISE AND CHALLENGE OF SUSTAINABLE AQUACULTURE 2 (2007); KATHRYN WHITE, BRENDAN O'NEILL, AND ZDRAVKA TZANKOVA, AT A CROSSROADS: WILL AQUACULTURE FULFILL THE PROMISE OF THE BLUE REVOLUTION? 4 (2004).

[5] THE WORLD BANK, *supra* note 4, at 2.

industry has enjoyed "giant strides in productivity, intensification and integration, industry concentration, and diversification in product, species, and culture systems."[6] On the other hand, the industry has begun to cause its own set of problems, including environmental degradation and coastal user conflicts.[7] Achieving aquaculture's full potential to meet the world's nutritional, environmental, and economic needs will be a difficult task in light of the current problems associated with aquaculture practice. But the history of the development of the aquaculture industry can serve as a cautionary tale as the industry moves forward. Specifically, aquaculture, historically viewed as a substitute for dwindling wild fish stocks, a solution to the exploitation of a global commons, should also be viewed as a tragedy of a separate, but equally serious, nature. Without re-characterizing aquaculture as capable of creating tragedies, the industry will likely continue to fail to meet the primary purpose for which it was developed: to create a sustainable substitute for wild fisheries.

This Paper traces the history of aquaculture from ancient China until the present, highlighting the various degrees of, and reasons for, aquaculture's popularity at different points throughout history. Part II begins with a discussion of the famous Tragedy of the Commons, a rubric for conceptualizing modern environmental problems, explaining the theories of the tragedy (A) by exploitation and (B) by pollution and (C) briefly describing the typical solution advocated to mitigate the tragedy. Part III tells the story of aquaculture's deep history, discussing (A) the origins of the industry in ancient China and Rome, (B) aquaculture's growing popularity during the medieval era, (C) aquaculture's hibernation during the Industrial Revolution, as fishing picked up steam, (D) the resurgence of the industry during the twentieth century, and, finally, (E) the current state of the industry and the scarcity of direct regulation of

[6] *Id.* at 2.
[7] *Id.* at 2.

the industry. Through Part III, it becomes clear that aquaculture's resurgence in modern life occurred in large part as a response to environmental harms of other protein-providing food industries, like fishing and rearing of livestock. In other words, the modern surge in popularity of aquaculture is based largely on environmental, perhaps conceptualized as economic, concerns. Part IV steps back to look briefly at (A) the benefits of, and (B) the costs imposed by, the practice of aquaculture. Part V discusses (A) the present and future trends and challenges of the aquaculture industry and (B) briefly analyzes the ways in which the patchwork of laws governing aquaculture is poorly suited to the task of making aquaculture a sustainable substitute to wild fisheries. Part VI briefly concludes.

This Paper applauds the development of the aquaculture industry as an environmentally beneficial, economically sound, and domestically responsible path for American food production; ultimately, though, this Paper argues that for aquaculture to realize its full potential along each of these avenues, it must be re-conceptualized as the instigator of problems of its own and be regulated as such. It must draw lessons from its history to become a sustainable,[8] "green" blue revolution.

[8] This Paper adopts the definition of the term "sustainable aquaculture" used the Food and Agriculture Organization of the United Nations, which defines it to mean:

> The management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic material, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, TECHNICAL GUIDELINES FOR RESPONSIBLE FISHERIES, AQUACULTURE DEVELOPMENT 3 (1997); *see also* JOHN E. BARDACH, SUSTAINABLE AQUACULTURE 5 (1997)

II. The Tragedy of the Commons

Thomas Hardin's celebrated article, *The Tragedy of the Commons*,[9] sets the backdrop for this story, as aquaculture can be characterized as both a solution to and cause of different negative impacts on locally, nationally, and globally held common-pool resources.[10] Thus, this Part briefly summarizes the theory of the tragedy of the commons to set the stage for the historical account of aquaculture's development.

Hardin's article initially explains the commons by describing a town common, a field on which all the local herdsmen graze their sheep, and notes that "[a]s a rational being, each herdsman seeks to maximize his gain."[11] The herdsman "asks, '[w]hat is the utility *to me* of adding one more animal to my herd?'"[12] He quickly discovers that the utility is positive: he gains the utility of *positive one* since he receives all of the proceeds from the animal he grazes on the commons; but the negative component, which is calculated as a function of the overgrazing produced by the addition of one animal to the commons, is shared by all the herdsmen using the commons, thus *a fraction of negative one*.[13] Thus, Hardin concludes "the only sensible course for him to pursue is to add another animal to his herd. And another and another," because the benefits to him exceed the readily foreseeable costs to him.[14] When logic compels such a result,

[9] Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243, 1243–48 (1968).
[10] Although often credited with this theory, political economist Elinor Ostrom notes that Hardin was not the first to recognize the tragedy. ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 2 (1990). Aristotle first described the tragedy: "what is held in common by the largest number of people receives the least care." ARISTOTLE, POLITICS, BOOK II, CH. 3, lines 33–34 (C.D.C. Reeve trans. 1998); *see also* OSTROM, *supra*, at 2; H. Scott Gordon elaborated on the commons notion set forth by Aristotle more than a decade before Hardin's famous piece in his 1954 article in the Journal of Political Economy. H. Scott Gordon, *The Economic Theory of a Common-Property Resource: The Fishery*, 62 J. Political Economy 124, 124–42 (1954). Gordon focused his analysis on the commons of the global fishery and the problems of exploitation. *Id.* Ostrom also credits Hobbes and William Forster Lloyd with similar observations. OSTROM, at 2–3.
[11] Hardin, *supra* note 9, at 1244.
[12] *Id.*
[13] *Id.*
[14] *Id.*

all men will increase their herds without limit and "therein," Hardin explains, "is the tragedy."[15] "Freedom in a commons brings ruin to all."[16] The tragedy as Hardin describes it occurs in two ways: *exploitation* of common-pool resources and *pollution* of common-pool resources.

A. Exploitation of the Commons

The concept of exploitation of the commons involves removing something from a common pool. Hardin's classic commons example, the cows grazing on public property, is an example of exploitation, where the positive utility gained by removing resources (grass) from a commons (a field) by some mechanism (grazing) is more than the small amount of degradation your individual action causes. But ultimately, overexploitation (overgrazing) results.

H. Scott Gordon, whose article *The Economic Theory of a Common-Property Resource: The Fishery*, preceded Hardin's work by more than ten years, focused on exploitation, specifically in the form of overfishing wild fish stocks.[17] Hardin also uses the example of wild fisheries, noting that "professing to believe in the 'inexhaustible resources of the oceans,' [maritime nations] bring species after species of fish and whales closer to extinction."[18] Other scholars have similarly recognized the tragedy inherent in overfishing. For example, Professor Fikret Berkes explains that: "Fish populations are classical examples of common property resources and tend to decline over time."[19] This tragedy is also true in the context of fishing, where the positive utility of extracting one fish (the sale or consumption of one fish) far exceeds the negative effect removing one fish has on the common-pool resource (the entire fishery). To fishermen, the

[15] *Id.*
[16] *Id.*
[17] Gordon, *supra* note 10, at 124–142.
[18] Hardin, *supra* note 9, at 1245.
[19] *See* Fikret Berkes, *Fishermen and 'The Tragedy of the Commons*,' 12 Envtl Conservation 199, 199–206 (Sept. 1985). While recognizing the common conception that fishing of wild stocks is the poster-child for the tragedy of the commons, Professor Berkes argues that fish and exploitation of fish populations do not fit as neatly into the Commons paradigm as Hardin assumed given the emergence of formal and informal management schemes to limit overfishing. *Id.*

ocean understandably appears to be a deep, inexhaustible source of fish, as the exploitation of the underwater resource is arguably less salient than that of an open, visible field. Thus, the rational fishermen will continue to fish until the tragedy of full exploitation ensues.

B. Pollution of the Commons

Although the classic tragedy-of-the-commons problems are characterized by exploitation of a common resource, Hardin explains that "[i]n a reverse way, the tragedy of the commons reappears in problems of pollution."[20] Anthropogenic pollution occurs not when human activity removes something *from* the environment, but rather when human activity puts something *into* the commons in a way that ruins its overall utility.[21] Because polluters often enjoy the full benefit of not having to pay for the refuse they emit, whether it is emissions of sulfur dioxide from a power plant into the ambient air or effluent of raw sewage from a municipal sewage treatment plant into a nearby river, but only suffer a small fraction, if any,[22] of the cost of pollution of the resource, the rational polluter continues to pollute. Hardin's examples include: "sewage or chemical, radioactive, and heat wastes into water; noxious and dangerous fumes into the air; and distracting and unpleasant advertising signs into the line of sight."[23] Thus, each of us rational polluters slowly "foul[s] our own nest."[24]

C. Solving the Tragedy

According to Hardin, the solution to the tragedy of the commons lies in "[m]utual coercion mutually agreed upon," whether by private market or public regulatory mechanisms.[25]

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[20] Hardin, *supra* note 9, at 1245.
[21] *Id.*
[22] Pollution may not result in any negative effects on the polluter, as when a sewage treatment plant pollutes a river, which quickly disperses the effluent downstream, or when a factory's air emissions are quickly swept downwind.
[23] Hardin, *supra* note 9, at 1245.
[24] *Id.*
[25] *Id.* at 1247.

In other words, to solve the commons one has to bind him- or her-self to act irrationally, to forgo short-term profit in the interest of long-term sustainability. This Paper posits aquaculture arose as a market solution, a non-coercive but government-encouraged response to the tragedy of the ocean commons by exploitation in the form of overfishing. Indeed, aquaculture arguably offers huge advantages over, and benefits to the environmental health of, our wild fish stocks and our oceans and inland aquatic environments. However, this Paper posits, aquaculture must be re-characterized as capable of creating a tragedy of its own. In other words, while aquaculture offers the promise of mitigating the exploitation of the ocean commons, it may create tragedies by pollution of oceans, lakes, rivers, and other host water bodies and, paradoxically, exploitation of wild fish stocks to aid aquaculture operations. Without "[m]utual coercion mutually agreed upon," aquaculture's future may be less robust and less promising than its history would otherwise foretell. [26]

III. The History of Aquaculture

This Part traces the long, complicated history of the practice of aquaculture worldwide. Section A begins by briefly describing the deep roots of aquaculture in ancient China and ancient Rome to give a sense of the ancient origins of, and reasons for, the practice of aquaculture. Section B outlines the rise of aquaculture during the Medieval and Renaissance Eras, explaining how and why aquaculture became more popular through that time. Section C documents the decline of aquaculture practice during the industrial revolution, when fishing became more popular and the demand for product from inland and coastal fish farming declined. Part D turns almost exclusively to the aquaculture industry in the United States, summarizing the resurgence

[26] *Id.*

of the industry on American shores during the twentieth century, and Part E describes the current state of the industry and the scarcity of direct regulation of the industry. The history of aquaculture has been marked by dramatic shifts in supply and demand in a close-knit relationship with the waves of supply of wild-caught fish. From ancient times, aquaculture has arisen to fill gaps in the availability of other forms of protein and, more recently has been viewed as a sustainable alternative to wild fish.

A. Ancient Aquaculture

Aquaculture has deep, yet modest, roots in history. In one form or another, aquaculture has been practiced for millennia, with roots dating back to ancient China well before 1000 BC.[27] Historians posit that the raising of fish in captivity began in ancient China just as populations were abandoning nomadic life and taking up settlements and that the industry likely developed to compensate for the ancient society's lack of fishing skills, to provide a constant supply of food, and to show wealth of individual stockholders.[28] The earliest signs of aquaculture practice are found on oracle bones containing marks used by priests to predict the future as well as to predict "favorable times to gather fish,"[29] and the earliest records of fish in captivity date back to the Chou Dynasty, from 1112 to 221 BC.[30] The first emperor of the Xia Dynasty, Si Wen Ming, wrote in 2070 BC "about the laws that regulated the periods during which fish spawn could be harvested," demonstrating that ancient societies not only practiced a rudimentary form of aquaculture, but also had an interest in regulating the industry.[31] Aquaculture flourished for a

[27] HERMINIO R. RABANAL, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, THE HISTORY OF AQUACULTURE § 2.1 (1988). Some accounts place the origins of aquaculture in ancient Egypt at around 2500 BC. COLIN E. NASH, THE HISTORY OF AQUACULTURE 15 (2011).
[28] *See* RABANAL, *supra* note 27, at § 2.1; NASH, *supra* note 27, at 12.
[29] NASH, *supra* note 27, at 12.
[30] *Id.*
[31] *Id.*

millennium following Fan Li's writings on the merits of culturing carp in 475 BC.[32] After Fan Li's time, aquaculture proliferated throughout various parts of the world in the fourth and fifth centuries BC. In India, the first references to keeping fish in captivity occurred in approximately 300 BC.[33] The Sumerians and Babylonians reportedly raised fish in impoundments along the Tigris and Euphrates Rivers from circa 400 BC.[34]

Aquaculture was also very popular in ancient Rome,[35] so popular, in fact, that many noteworthy figures wrote about it. For example, Cicero and Pliny kept accounts of the values of raising fish and the various places in which fish were raised.[36] Columella, the most famous agricultural writer of Ancient Rome, wrote a section of his treatise *Of Husbandry in Twelve Books* devoted entirely to fishponds.[37] The reasons for the widespread practice of aquaculture during this time were again diverse. For example, wealthy Romans' "*vivariae piscinae*," or

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[32] *Id.* at 13; *see also* RABANAL, *supra* note 27, at § 2.2. According to Nash, ancient Chinese societies had to stop fishing for carp, pronounced "lee" at that time, because the 618 AD emperor Li found it insulting. NASH, *supra* note 27, at 13. This "forced the peasant farmers to search for other species . . . and to develop new husbandry practices." *Id.*

[33] NASH, *supra* note 27, at 15.

[34] *Id.* at 15–16.

[35] *See* Annalisa Marzano, Fishing and Aquaculture in the Roman Mediterranean, Address at the Institute for the Study of the Ancient World, New York University (Feb. 22, 2011).

[36] *See* Marcus Tullius Cicero (60-59 BC), *Epistulae ad Atticum I.20, I.19, II.9*, *in* LOEB CLASSICAL LIBRARY (Harvard Univ. Press 1999) (translated by Shackleton-Bailey, D.R.); Pliny, *Naturalis Historia*, *in* LOEB CLASSICAL LIBRARY (Harvard Univ. Press 1952) (translated by H. Rackham); *see also* KARL-WILHELM WEEBER, LUXUS IM ALTEN ROM: DIE SCHWELGEREI, DAS SUSSE GIFT CH. 3 & 4 (2003) (describing Cicero's writings on fish farming in Ancient Rome).

[37] Lucius Junius Moderatus Columella, Of Fish-ponds, and of feeding on Fishes, Chap. XVI, *in* OF HUSBANDRY IN TWELVE BOOKS (Reprinted in 1745 for A. Millar). Columella devotes five pages of his ancient treatise to the farming of fish which he calls, "aquatile cattle" or "scaly flocks." *Id.* Columella explained that his reluctance to write on the subject was defeated by the importance aquaculture played in that ancient society:

> For tho' I think, that the gain, redounding from [the care and management of fishes], is most unsuitable and alien to Husbandmen . . . nevertheless I shall not omit it. For our ancestors took great delight in, and applied themselves much to, these things . . . . For that ancient, rustic progeny of *Romulus* and *Numa* valued themselves mightily upon this, and thought it a great matter, that, if rural life were compared with a city life, it did not labour under the want of, or come short in, any part of riches or wealth whatever. Wherefore, they not only stored the fish ponds, which they themselves had built, with great numbers of fishes, but also filled the lakes, which nature had formed, with spawn, or young fishes, brought from the sea.

Id. at 371.

living pools, were "extremely popular" to provide seafood to inland residents and to serve as "prestigious showpieces."[38] According to historian Colin E. Nash, "[m]ore practical *piscinae* in this ancient world were probably the defensive moats of the larger walled fortifications and cities."[39] Aquaculture thus enjoyed a rich ancient history, by many accounts dating back four millennia. While ancient fish farmers likely only captured and raised fry in inland or coastal ponds rather than breeding fish in captivity, due to limited scientific understanding, they clearly valued the practice of fish farming for multiple reasons, not the least of which was to provide an otherwise unavailable, or inconvenient, source of protein to inland dwellers. However, the practice of aquaculture in ancient times was still fairly modest relative to fishing of wild stocks, with a robust commercial aquaculture market yet to develop along major trade routes.

B. The Medieval Era through the Renaissance: Aquaculture Abounds

The early Medieval Era enjoyed a more vigorous aquaculture industry,[40] but the feudal system wreaked havoc on the supply of fishponds throughout Europe.[41] Because peasants could not own land, they were also barred from owning fishponds, a ban reinforced under the *Magna Carta* of 1297, which included a clause banning fish weirs, or traps.[42] However, the community pond became popular in Eastern Europe, "one of the first steps in clear and private ownership of that which was a common property resource,"[43] when Charles the IV, a Roman emperor and king of Bohemia in the fourteenth century, "commanded estate holders and cities to build

[38] NASH, *supra* note 27, at 16–17. *See also, generally*, JAMES HIGGINBOTHAM, PISCINAE: ARTIFICIAL FISHPONDS IN ROMAN ITALY (1997).
[39] NASH, *supra* note 27, at 22.
[40] *See generally* Brian N. Fagan, Fish on Friday: Feasting, Fasting, and the Discovery of the New World (2006); NASH, *supra* note 27, at 25–39.
[41] NASH, *supra* note 27, at 28.
[42] MAGNA CARTA, 1297, 1239–1307, Edward I (1297), § 23 ("All fish weirs (kidelli) on the Thames and the Medway and throughout England are to be entirely dismantled, save on the sea coast.").
[43] NASH, *supra* note 27, at 28.

fishponds 'so that the kingdom would abound in fish and mist.'"[44] Outside of Europe, during the fourteenth and fifteenth centuries, the practice of fish farming proliferated throughout Southeast Asia, with the invention of *tambaks* in Eastern Java, large mats of nutrient-rich algae off of which healthy populations of fish were able to survive.[45] Fishponds were also common throughout the Pacific Islands, and South American societies created fishponds in floodplains as early as the sixteenth century, before the arrival of the Spanish.[46]

Ancient and medieval fish ponds, as described by Fan Lin, Columella, and, eventually, Chaucer, in the prologue to *The Canterbury Tales*,[47] were devoted to stocking wild fish in inland ponds, whereas today aquaculture generally consists of "artificial fertilization of eggs and breeding of fish in hatcheries."[48] As the Renaissance dawned, so too did more advanced methods for rearing fish. Ioannes Dubravius wrote of carp breeding in his 1547 treatise *Jani Dubravil de piscinis et piscium qui in illis alantur libri quinquae.*[49] Shortly thereafter, in 1600, John Taverner published a treatise describing aquaculture, generally, as well giving as breeding advice.[50] A detailed, famed thesis on raising fish called *A Discourse of Fish and Fish Ponds* was published in 1713, "Done by a Person of Honour," the Englishman Roger North.[51] Ludwig

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[44] *Id.* at 28.
[45] *Id.* at 33.
[46] *Id.* at 34–36.
[47] GEOFFREY CHAUCER, THE CANTERBURY TALES l. 349–50 (V.A. Kolve & Glending Olson eds., 1775) (discussing a man who "hadde he . . . many a breem and many a luce in stew"); *see also* Whit Richardson, *The Mastery of Fish*, LAPHAM'S Q. (Feb. 19, 2012). "Breem" and "luce" mean bream and pike, while "stew" refers to a fishpond. NASH, *supra* note 27, at 28.
[48] Richardson, *supra* note 47.
[49] NASH, *supra* note 27, at 40 (citing IOANNES DUBRAVIUS, JANI DUBRAVIL DE PISCINIS ET PISCIUM QUI IN ILLIS ALANTUR LIBRI QUINQUAE (1547)).
[50] NASH, *supra* note 27, at 42 (citing JOHN TAVERNER, CERTAIN EXPERIMENTS CONCERNING FISH AND FRUITS (1600)). Gervais Markham published a similar treatise a quarter century later, so similar, in fact, that Nash posits "one might expect plagiarism." *Id.*
[51] HON. ROGER NORTH, DISCOURSE OF FISH AND FISH PONDS (DONE BY A PERSON OF HONOUR), LONDON, PRINTED FOR E. CURLL (1913).

Jacobi wrote about hatching of trout and salmon in 1763.[52] In many parts of the world, the practice of aquaculture was booming, and societies were talking and writing about it.

Yet the expansion of, and worldwide interest in, aquaculture soon dwindled with the invasion of the Mongols in China in the fifteenth century and the Reformation of England in the sixteenth century.[53] To remedy the decreased demand for fish in light of the increasing demand for land and fresh water, in 1562 Queen Elizabeth I declared that "every Wednesday was 'to be used and observed as a fish day,'" with disobedience punishable by "fines and other penalties," thus sparking the civil development of fishing vessels and other infrastructure.[54] The young United States of America showed similar interest in and concern for its fisheries and the supply and demand for fish products, as demonstrated by Thomas Jefferson's Report to Congress on the Subject of the Cod and Whale Fisheries in 1791.[55] The Report notes that the fishing and whaling industries, "annihilated during the war, have been, in some degree, recovered since: but they labour under many and heavy embarrassments, which, if not removed, or lessened, will render the fisheries every year less extensive and important."[56] Thus, the Medieval and Renaissance Eras demonstrate the abundance of aquaculture practice throughout the world, alongside some trends of decreased aquaculture production due to land use and ownership restrictions and a new emphasis on the industry on fishing, a trend that would continue to define the field of fish protein production throughout the Industrial Revolution.

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[52] EARL LEITRITZ & ROBERT CONKLIN LEWIS, UNIV. OF CALIFORNIA DIV. OF AGRICULTURE AND NATURAL RESOURCES, TROUT AND SALMON CULTURE: HATCHERY METHODS 7 (1980) (describing Ludwig Jacobi as the first person accomplished in "the art of trout culture"); *see also* Richardson, *supra* note 27.
[53] NASH, *supra* note 27, at 44.
[54] *Id.* at 44–45. Shakespeare referenced the disdain for this law in Act 1, Scene I of *King Lear*, hinting that good men ascribed by the adage "*And to eat no fish*," in contravention of the Queen's law. *See* William Shakespeare, *King Lear*, *in* THE WORKS OF SHAKESPEARE VOL. III 64 (Howard Staunton, John Gilbert, Edward Dalziel, & George Dalziel, eds., 1864); *see also id* at 117 (providing historical commentary to explain the quote's meaning.
[55] THOMAS JEFFERSON, REPORT TO CONGRESS OF SECRETARY OF STATE ON THE SUBJECT OF THE COD AND WHALE FISHERIES (Feb. 1, 1791) (pub. by order of the Senate of the United States, Philadelphia).
[56] *Id.*

C. The Industrial Revolution: The Rise of Fishing & Decline of Aquaculture

The common practice of fish farming that developed during medieval times further waned as the Industrial Revolution began in Europe. Whereas during the former eras fish farming had been an efficient, cost-effective means of delivering protein to inland societies, it became less attractive as marine fishing became more popular. The development of marine fishing technology, inland railway transportation, and preservation techniques spurred industrial fishing and simultaneously contributed to a global decline in aquaculture practice. Fishing in distant waters was made possible by the use of multiple vessels to perform different tasks, with fast boats carting product back to shore and the larger trawlers staying out at sea.[57] Steam engine fishing boats first emerged in 1854, with an effective, market-viable model available as early as 1880.[58] These fishing boats, which made deep sea fishing possible, made their way to the United States, where they were readily launched, at around the turn of the century.[59] Fishing technology also improved with mechanization, such as the invention of beam trawls and otter trawls, making large catches possible.[60] Moreover, the availability of machine-made ice allowed for catches farther out from shore and for the possibility of inland transport, and the invention of steam-powered rail facilitated quick inland transport.[61]

According to the official Catalogue for the Great International Fisheries Exhibition of 1883, in the United States, the exploitable fisheries "increased in extent and value to a degree without parallel in their previous history" due:

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[57] NASH, *supra* note 27, at 46.
[58] *Id.*
[59] Northeast Fisheries Science Center, National Oceanic and Atmospheric Administration, History of Groundfishing Industry of New England, http://www.nefsc.noaa.gov/history/stories/groundfish/grndfsh1.html (last visited Mar. 11, 2012).
[60] NASH, *supra* note 27, at 46.
[61] *Id.*

(1) to the introduction of the improved methods of refrigeration, by means of which sea-fish are distributed widely throughout the interior of the country;
(2) to greatly extended facilities for steam transportation;
(3) to the extended introduction of methods of packing in hermetically-sealed cans, and of more attractive methods of preparing for market the several kinds of dried and smoked fish;
(4) to the introduction of improved vessels and apparatus by means of which the expense of capture has been greatly diminished; and
(5) to the efforts of a considerable number of enthusiasts, anglers, statesmen, and philanthropists, who, by the organisation of the Fishery Societies, State Fish Commissions, and the United States Fish Commission, and by their publications, have awakened public interest, secured extensive appropriations of public money for the propagation and acclimation of useful fishes, and have demonstrated the value to the country of many previously neglected fishery resources.[62]

All this change, which occurred "in a brief period of 50 years,"[63] made fishing extraordinarily popular in the late nineteenth and early twentieth centuries, and effectively made aquaculture a story of the past, irrelevant to the realities food production in the nineteenth and early twentieth centuries.

D. Aquaculture's Resurgence at the Turn of the Century

However, this lull in aquaculture activity ended in the twentieth century when it became apparent that fishing was unsustainable over the long term. The ease of large-scale deep-sea fishing facilitated by technological developments during the Industrial Revolution had caused an "explosion in uncontrolled harvesting of all continental shelves within two to three hundred miles."[64] The popularity of offshore fishing, combined with pollution from the newly mechanized fleet, wreaked havoc on coastal fish populations.[65] Similar depletion occurred on inland waters, like rivers and estuaries, mostly due to the effluent from new industrialized

[62] GREAT INTERNATIONAL FISHERIES EXHIBITION, 1883: OFFICIAL CATALOGUE (London, 1883).
[63] NASH, *supra* note 27, at 46.
[64] *Id.*
[65] *Id.*

activity on riverbanks in the United States and Europe.[66] Even as early as the turn as the turn of the century, when steam-powered fishing boats arrived on U.S. shores, "there was concern that the new technology was quite powerful, and could threaten the productivity of the stocks" and "[s]cientific investigations of the time warned that the new technology should be applied judiciously — but had little effect on fishing."[67] Development of dams at the turn of the century did not help the situation, but rather contributed to pollution problems and cut off many fish species from their up-river spawning grounds.[68] Decreased stream flows from increases in appropriations in water-poor western states also likely made fish species' survival more difficult.[69]

The first fisheries agency in the United States, which has since morphed into today's National Marine Fisheries Service ("NMFS/NOAA Fisheries") under the auspices of the National Oceanic and Atmospheric Administration ("NOAA"), [70] was formed largely in response to these concerns. The latter agency was created after Spencer Fullerton Baird, Assistant Secretary of the Smithsonian Institution, wrote to Congress in 1871 stressing that the United States was seeing a drastic depletion in "food fishes" in both coastal and inland waters and

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[66] *Id.* at 48; *see also* RICHARD J. LAZARUS, THE MAKING OF ENVIRONMENTAL LAW (2006) (describing the "many dissenting voices" concerned about water pollution at the end of the nineteenth century and during the early twentieth century).

[67] Northeast Fisheries Science Center, National Oceanic and Atmospheric Administration, History of Groundfishing Industry of New England, http://www.nefsc.noaa.gov/history/stories/groundfish/grndfsh1.html (last visited Mar. 11, 2012).

[68] *See* JOSEPH L. SAX, BARTON H. THOMPSON, JR., JOHN D. LESHY, & ROBERT H. ABRAMS, LEGAL CONTROL OF WATER RESOURCES 1027 (4th ed. 2006) (explaining that dams "can change the amount of dissolved oxygen in downstream waters, add various minerals and other harmful nutrients, and raise or lower downstream water temperatures"); *Nat'l Wildlife Federation v. Gorsuch*, 693 F.2d 156, 161–64 (1982) (describing generally the problems caused by "dam-induced water quality changes").

[69] *See* GEORGE CAMERON COGGINS, CHARLES F. WILKINSON, JOHN D. LESHY, ROBERT L. FISCHMAN, FEDERAL PUBLIC LAND AND RESOURCES LAW 487 (6th ed. 2007) (describing the prior appropriation doctrine as emerging in western states in part because of the shortage of water in those states).

[70] National Oceanic and Atmospheric Administration, History of the National Marine Fisheries http://www.history.noaa.gov/legacy/nmfshistory.html (last visited Mar. 11, 2012). NOAA itself, the umbrella agency in charge of a variety of national issues in addition to fisheries, was created 1970, a derivative of three long-standing agencies: the United States Coast and Geodetic Survey, formed in 1807, the Weather Bureau, formed in 1870, and the Bureau of Commercial Fisheries, formed in 1871. *Id*.

describing potential remedial measures.[71] Soon thereafter Mr. Baird spoke on the Floor of the House, explaining that:

> [I]t has come to the knowledge of scientific men that fishes are departing from our coast, either from the imperfect mode of catching them or some change not well understood by these scientific men, so that this source of food as well as of fertilizing material . . . is fast passing away. . . . These scientific men are desirous of examining and experimenting on these fishes to ascertain their character and habits sufficiently to see whether it is possible to adopt some regulations to keep them upon the fishing grounds . . . to ascertain whether there can be any regulation in the mode of catching these fish which will obviate this evil.[72]

Congress reacted quickly, despite opposition and ridicule from several notable members,[73] by passing a bill, thereafter signed by Ulysses S. Grant, which established the Office of the Commissioner of Fish and Fisheries in 1871 ("the Commission" or "the Office"). The first Chairman of the Office was, appropriately, Spencer Fullerton Baird.[74] The legislation directed the Commission to investigate "the causes of decrease in the supply of useful food-fishes of the United States, and of the various factors entering into the problem; and the determination and

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[71] *Id*.

[72] Cong. Globe, 41st Cong., 3d Sess. 585 (1871) (statement of Mr. Spencer F. Baird, Assistant Secretary Smithsonian Institution).

[73] The debate, as reported in the Congressional Globe, reads:

> Mr. Farnsworth: Add to your resolution a direction to inquire in reference to grasshoppers and potato-bugs.
> Mr. Dawes: My friend from Illinois may think this is a subject of no importance whatever; but I assure him that along the coasts of New Jersey and New York, and all up our coast to the British possessions, this is a matter of vital importance.
> Mr. Farnsworth: So is the inquiry in reference to the potato bug.

Cong. Globe, 41st Cong., 3d Sess. 585 (1871).

[74] Joint Resolution for the Protection and Preservation of the Food Fishes of the Coast of the United States, H.R.J. Res. 22, 44th Cong. (1871) (enacted). The modern analogue to this legislation appears at 16 U.S.C. § 744, directing, in relevant part, that:

> The Secretary of the Interior or the Secretary of Commerce, as appropriate, shall prosecute investigations and inquiries on the subject, with the view of ascertaining whether any and what diminution in the number of the food fishes of the coast and the lakes of the United States has taken place; and, if so, to what causes the same is due; and also whether any and what protective, prohibitory, or precautionary measures should be adopted in the premises; and shall report upon the same to Congress.

16 U.S.C. § 744 (2006).

employment of such active measures as may seem best calculated to stock or restock the waters of the rivers, lakes and the sea."[75]

Similar institutions emerged in Europe as well, with the appointment of a Royal Commission in 1863 and 1873 solely devoted to the study of British fisheries.[76] At the same time, nongovernmental institutions emerged to study these issues. In 1870, citizens formed the American Fish Culturists Association, now known as the American Fisheries Society,[77] while similar citizen groups spawned throughout Europe. Even the famed Linnaean Society of London[78] and Royal Society of Edinburgh[79] stressed the importance of studying marine science.

While fishing enthusiasts within and outside of government institutions discussed the fate of fishing with great concern, aquaculture slowly reentered the picture as a viable way to fix the depletion occurring in inland and coastal waters, alongside uncoordinated court battles to regulate water pollution, dams and water withdrawals. Aquaculture had entered state agriculturalists' agendas as early as 1804, when Reverend John Bachmann reported to the South Carolina State Agricultural Society on fertilizing and hatching brook trout.[80] Soon, efforts to culture fish species took off after publications like Charles Darwin's *The Origin of Species*,[81]

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[75] H.R.J. Res. 22, 44th Cong. (1871) (enacted).
[76] NASH, *supra* note 27, at 47.
[77] *See, e.g.*, AMERICAN FISH CULTURISTS' ASSOCIATION, PROCEEDINGS OF THE AMERICAN FISH CULTURISTS' ASS'N, 1872–1875 (1875); *see also* American Fisheries Society, This is AFS, http://fisheries.org/docs/about_afs.pdf (last visited Mar. 16, 2012).
[78] Proceedings of the Linnaean Society from as early as 1854 show presentations on the details of the life-cycles of many fish species throughout the world. *See, e.g.*, Robert Knox, Esq., M.D., *On the Food of Certain Gregarious Fishes*, PROCEEDINGS OF THE LINNAEAN SOCIETY OF LONDON 354 (1854) (communicated by William Yarrell, Esq., V.P.L.S.).
[79] The Royal Society of Edinburgh has celebrated marine science, specifically the study of fisheries, since the mid-nineteenth century. For example, in 1861 Sir William Jardine proposed "to give more detailed observations on the salmon fisheries of England and Wales than could be done in the compass of an official report . . . ." Sir William Jardine, Bart., F.R.S., *On the Condition of the Salmon Fisheries of England and Wales in 1861; with a Notice of Some of the Modes of Fishing, especially those practiced in the Severn and Wye*, 4 PROCEEDINGS OF THE ROYAL SOCIETY OF EDINBURGH 539 (1861).
[80] ROBERT R. STICKNEY, AQUACULTURE IN THE UNITED STATES: A HISTORICAL SURVEY 8 (1996).
[81] CHARLES DARWIN, ON THE ORIGIN OF SPECIES (Joseph Carroll ed., 2003) (originally published 1859).

discussing the adaptability of species to the environments in which they live, and Gregor Mendel's work on heredity in green peas, as recounted in *Experiments in Plant Hybridisation*.[82] These developments reinvigorated the field of biology and animal culture, as well as public interest in viewing captive aquatic species.[83] Aquariums became very popular at around this time, making relevant once again the plentiful research of aquaculture enthusiasts, like Ludwig Jacobi's groundbreaking work on incubation and captive rearing of fish[84] and works by both noted and amateur scientists of the time like Anton Gehin, Joseph Remy, Armand de Quatrefages, and Gottleib Boccius, the latter of whom wrote *A Treatise on the Production and Management of Fish in Freshwater by Artificial Spawning, Breeding, and Rearing* in 1848.[85] The French government finished work on very successful hatchery in 1862, which was replicated throughout the world as governments became more aware of the dangers of offshore fishing.[86] These efforts mainly arose to replenish natural populations of fish, but the inland rearing of fish by fish farming became more popular after rainbow trout were successfully raised at an aquarium in Paris from trout eggs shipped from the United States.[87]

In the United States, the focus of the remainder of this Paper, similarly exciting developments in aquaculture were occurring quietly while the marine fishing industry took off. Theodatus Garlick, a surgeon and the Vice President of the Cleveland Academy of Natural Science in Ohio, published a treatise on fish farming in the mid-nineteenth century in which he

[82] GREGOR MENDEL, EXPERIMENTS IN PLANT HYBRIDISATION (Cosimo Classics, 2008) (originally published in 1909).
[83] NASH, *supra* note 27, at 53.
[84] Aquamedia, An Introduction to Aquaculture Production, http://www.feap.info/production/default_en.asp (last visited Feb. 19, 2012); *see also* NASH, *supra* note 27, at 54. William Yarrell's later work was similarly helpful during this time. *Id.* at 55.
[85] NASH, *supra* note 27, at 56.
[86] *Id.*, at 57–61.
[87] *Id.* at 62.

described his successes in rearing brook trout from eggs.[88] While Garlick's work became the highlight of state agricultural fairs throughout the country, landowners and sport fishermen were the first to realize the potential of fish farming in the United States.[89]

But with the advent of common concern about polluted and exploited waters, aquaculture quickly became more than a wealthy man's hobby. The first commercial salmon hatchery opened in Maine a year before the development of the Office of the Commissioner of Fish and Fisheries.[90] When the Office opened, Commissioner Baird immediately demonstrated his commitment to solving the problems of declining fish stocks.[91] His 800-page *Report of the Commissioner* for 1871 and 1872, published after the full first year of the Commission's operation, demonstrates the detailed, comprehensive nature of Commissioner Baird's first official inquiry into the problem of declining fish stocks and potential legal solutions, particularly in coastal state legislatures.[92] Notably, among the questions the Report seeks to answer is:

> Have any steps been taken to increase the abundance of this fish by artificial breeding?[93]

Shortly after the establishment of the Office, Livingston Stone,[94] a noted culturist of the time, was appointed as a Deputy to Commissioner Baird and ordered to introduce cultured

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[88] THEODATUS GARLICK, M.D., ON THE ARTIFICIAL PROPAGATION OF CERTAIN KINDS OF FISH WITH THE DESCRIPTIONS AND HABITS OF SUCH KINDS AS ARE THE MOST SUITABLE FOR PISCICULTURE (1867).
[89] NASH, *supra* note 27, at 63.
[90] *Id.*
[91] For an extensive account of Spencer Fullerton Baird's accomplishments in the Office, see ALLARD C. DEAN, SPENCER FULLERTON BAIRD AND THE U.S. FISH COMMISSION (1978).
[92] SPENCER FRANKLIN BAIRD, COMM'R, U.S. COMM'N OF FISH AND FISHERIES, REPORT ON THE CONDITION OF THE SEA FISHERIES OF THE SOUTH COAST OF NEW ENGLAND IN 1871 AND 1872 (1873).
[93] BAIRD, *supra* note 92, at 6.
[94] In his position as United States Deputy Fish Commissioner, Mr. Stone wrote a comprehensive guide to farm-raising trout, called DOMESTICATED TROUT, HOW TO BREED THEM AND GROW THEM (1877).

populations of fish into rivers on both the East and West coasts to strengthen existing, dwindling populations.[95] Commissioner Baird also informally established the first government marine collecting station and marine study center in Woods Hole, Massachusetts in 1871.[96] In 1883 this center was formally deeded to the United States government, and it officially reopened as the first permanent government lab in 1885, complete with a large ocean hatchery.[97] Another government-funded ocean hatchery opened in Gloucester Harbor shortly thereafter.[98] At the turn of the century, the United States was home to hatcheries and fry stations in almost every state and a dominant exporter of fertilized fish eggs to countries around the world.[99] The United States became a leader in hatchery technology development and hosted many demonstration stands at the International Fishery Exhibition of 1883 in London.[100]

It is perhaps not surprising that the attention of the U.S. Office turned so quickly to aquaculture. First, the country's inland and coastal waterways and their respective fish populations were in dire condition from industrial pollution, logging, and overfishing. Second, Stone and Baird were also the founders of the budding American Fish Culturists' Association, discussed above, avid advocates of the developing field of aquaculture.[101] While other parts of the world were more reticent to acknowledge the problems of overfishing and pollution and the potential solution apparent in fish farming and re-propagation, [102] the United States launched a

[95] *See* Jerry C. Towle, *Authored Ecosystems: Livingston Stone and the Transformation of California Fisheries*, 5 ENVTL. HISTORY 54, 54–77 (2000); NASH, *supra* note 27, at 65; Northeast Fisheries Science Center, Historical Highlights 1870's, http://www.nefsc.noaa.gov/history/timeline/1870.html (last visited Mar. 15, 2012).
[96] Northeast Fisheries Science Center, Fisheries Historical Highlights, 1870s, http://www.nefsc.noaa.gov/history/timeline/1870.html (last visited Mar. 13, 2012).
[97] *Id.*; *see also* NASH, *supra* note 27, at 72.
[98] NASH, *supra* note 27, at 72.
[99] *Id.* at 66.
[100] GREAT INTERNATIONAL FISHERIES EXHIBITION, 1883: OFFICIAL CATALOGUE (London, 1883).
[101] NASH, *supra* note 27, at 65.
[102] For example, T.H.H. in his inaugural address at the 1883 Great International Fisheries Exhibition, explained that he did not see the problem to be as widespread as some of his American counterparts believed:

strong effort to build a local aquaculture industry early on, led by the passionate Spencer Fullerton Baird.[103]

The following half-century was marked by the slow and steady development of aquaculture infrastructure in the face of decreased demand for aquaculture products and further depletion of ocean resources both in the United States and abroad. Governmental support for aquaculture waned in the early twentieth century as the country faced World War I, a Great Depression, and an agricultural crisis.[104] As the Dust Bowl swept across the southern United States,[105] American politicians deemed it more important to save an indispensable farming industry than to develop further the nascent aquaculture industry, which was still seen as a possible back up to the precarious fishing industry. Moreover, global demand for fish was still low,[106] especially in the United States where the national population in 1901 was only slightly over seventy-six million people.[107] While some technological advances quietly occurred during this time, as discussed below, this period was one of dormancy for the aquaculture industry in the United States. Nash calls aquaculture's failure "to capitalize on the excitement generated by the International Fishery Exhibition, and to make the complete transition from research and

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> I believe, then, that the cod fishery, the herring fishery, the pilchard fishery, the mackerel fishery, and probably all the great sea fisheries, are inexhaustible; that is to say, that nothing we do seriously affects the number of the fish. And any attempt to regulate these fisheries seems consequently, from the nature of the case, to be useless. There are other sea fisheries, however, of which this cannot be said.

THOMAS HENRY HUXLEY, INAUGURAL ADDRESS, FISHERIES EXHIBITION, LONDON (1883). In the audience sat the U.S. delegate, Commissioner Baird, who felt very differently. GREAT INTERNATIONAL FISHERIES EXHIBITION, 1883: OFFICIAL CATALOGUE (London, 1883).

[103] Commissioner Baird's tireless efforts to promote aquaculture and to save dwindling wild fish populations ended with his death on August 17, 1887, but his legacy lived on in the Commission, the 1065 articles and books he published throughout his career, many on the subject of aquaculture, and the widespread recognition throughout the United States of aquaculture's commercial potential. *See* STICKNEY, *supra* note 80; DEAN, *supra* note 91.

[104] NASH, *supra* note 27, at 66.

[105] For a thorough documentation of the Dust Bowl and the United States' response, see DONALD WORSTER, DUST BOWL (2004).

[106] NASH, *supra* note 27, at 93.

[107] POPULATION ESTIMATES PROGRAM, POPULATION DIV., U.S. CENSUS BUREAU, HISTORICAL NATIONAL POPULATION ESTIMATES: JULY 1, 1900 TO JULY 1, 1999 (2000).

development to a viable economic industry between 1900 and 1950" the "greatest lost opportunity" of aquaculture's history."[108]

However, in the United States the slowed economy and wars did not bring the fish food industries to a complete halt. Congress's contributions to the fish resources industries came mostly in the form of conservation measures rather than subsidies to a substitute industry. For example, to address what it perceived to be the primary driver of depletion of inland fish resources, Congress enacted section 18 of the Federal Power Act of 1920, which requires the commission to include in hydropower licenses to private entities "fish ways" prescribed by the Secretaries of Interior or Commerce.[109] Congress also enacted the Fish and Wildlife Coordination Act of 1934, [110] which required consultation with federal and state wildlife agencies before a federal actor could impound or divert waters;[111] ordered that surveys of resources be conducted to inform state and federal actions affecting wildlife resources;[112] authorized expenditure of federal dollars to modify or add structures to projects to conserve wildlife resources through impoundment;[113] and directed the Bureau of Fisheries to use impounded waters for fish-culture stations.[114] Finally, Congress paid unique attention to the Columbia River Basin, authorizing appropriations to restore the salmon resources of that basin in the Mitchell Act of 1938.[115] The result of this influx of federal dollars was a large increase in

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[108] *Id.* at 93.
[109] *See* 16 U.S.C. § 811 (2006); *see also* COGGINS, WILKINSON, LESHY & FISCHMAN, *supra* note 69, at 543.
[110] 16 U.S.C. §§ 661–667e (2006).
[111] *Id.* at § 662(a).
[112] *Id.* at § 662(b).
[113] *Id.* at § 662(c).
[114] *See generally id* at § 662–663.
[115] Mitchell Act of 1938, Pub. L. No. 75-502 (1938). Section 2 of the Act provides:

> The Secretary of the Interior is further authorized and directed (1) to conduct such investigations, and such engineering and biological surveys and experiments, as may be necessary to direct and facilitate conservation of the fishery resources of the Columbia River and its tributaries; (2) to construct and install devices in the Columbia River Basin for the improvement of feeding and

hatcheries, often called mitigation hatcheries, cropping up alongside new dams throughout the United States.[116]

On the Eastern side of the country, Homer Swingle[117] at the Alabama Polytechnic Institute realized that with the devastation of the farming industry in the United States arose an opportunity to spread the practice of fish farming. The Institute became a "focal point" of technological development in aquaculture during the Great Depression and would soon become "one of the world's leading institutions in fish farming."[118] In approximately 1939, Gunnar Rollefson discovered how to grow live feed for cultured marine species that could be stored for long periods of time, the beginning of a long tradition of growing fish to feed fish.[119] Moreover, in the 1950s, marine scientists in Oregon first began using pelleted feeds supplemented with vitamins and minerals to speed fish development.[120] Lauren Donaldson, an assistant professor at the University of Washington, received government funding to study the effects of nuclear activity and heat from nuclear power plants on animals and the environment. Donaldson, a marine scientist by training, used this funding to hatch salmon that would return to his laboratories after trips to sea and to breed a "super trout" which laid three times as many eggs as and reached maturity in half the time of a normal trout.[121] These trout were raised in

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> spawning conditions for fish, for the protection of migratory fish from irrigation projects, and for facilitating free migration of fish over obstructions; and (3) to perform all other activities necessary for the conservation of fish in the Columbia River Basin in accordance with law.

Id. § 2.

[116] NASH, *supra* note 27, at 92.

[117] *See* I.B. Byrd, *Homer Scott Swingle*, 1 WILDLIFE SOCIETY BULL. 157, 157 (1973) (describing Mr. Swingle as "one of the greatest fisheries scientists who ever lived," whose "management methods are used world-wide to make fish available for protein-hungry people").

[118] NASH, *supra* note 27, at 93.

[119] *Id.* at 93–94.

[120] *Id.* at 91.

[121] *See* STICKNEY, *supra* note 80, at 164–65, 171, 217–19; NASH, *supra* note 27, at 99–100; *see also Science Creates 'Pedigreed' Line of 'Super-Trout,'* ELLENSBURG DAILY RECORD, Feb. 28, 1940, at 8; *Scientists Angling for Super Trout*, SPOKANE DAILY CHRONICLE, Dec. 6, 1979, 57.

confinement, for fear of their impact on natural environments, and prompted curiosity in aquaculture and breeding during and after World War II.[122] Federal interest in aquaculture resulted in two pieces of relevant legislation in the 1950s: the Saltonstall-Kennedy Act for Commercial Fisheries of 1954,[123] which required the Department of the Interior ("DOI") to conduct research and educational services funded by the United States Department of Agriculture, and the Fish-Rice Crop Rotation Farming Program Act of 1958,[124] which created the United States Fish and Wildlife Service ("FWS") Fish Farming Experimental Station at Stuttgart and required cooperative work by United States Department of Agriculture ("USDA") and DOI.

After World War II, though, commercial fishing again dominated the food fish supply on the global landscape, in part because the coasts had been left relatively untouched by commercial fishermen during the war and stocks had replenished in record numbers.[125] The United Nation Food and Agriculture Organization ("FAO")[126] reports that "[f]or the two decades following 1950, world marine and inland capture fisheries production increased on average by as much as 6 percent per year, trebling from 18 million tonnes in 1950 to 56 million tonnes in 1969."[127] Thus, aquaculture during the first half of the twentieth century was in a period of dormancy, while innovators in fish farming technology slowly but steadily pushed ahead.

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[122] NASH, *supra* note 27, at 100.
[123] 15 U.S.C. §§ 713 *et seq.* (1954).
[124] 16 U.S.C. §§ 778 *et seq.* (1958).
[125] NASH, *supra* note 27, at 103–04.
[126] The FAO was founded in 1945 as United Nations agency, with its Washington D.C. headquarters opening in 1951. Food and Agriculture Organization of the United Nations, A Short History of the FAO, http://www.fao.org/UNFAO/histo-e.htm (last visited Mar. 12, 2011). Its Constitution indicates that its international jurisdiction over fishing and aquaculture heralds from its earliest days, as it defines "agriculture" to include "fisheries [and] marine products . . . ." CONSTITUTION OF THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS ART. XVI (1945).
[127] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, THE STATE OF WORLD FISHERIES AND AQUACULTURE 3 (2000).

E. Modern Aquaculture and the Paucity of Regulation

The revival of fishing popularity at the expense of aquaculture's popularity did not last long, however. Rather, the dramatic increase in fishing production between 1950 and 1970 necessarily came to an end as fish stocks were overexploited first on the coasts and then on the deep sea. According to the FAO, during 1970s and 1980s, the average rate of increase of capture fisheries production decreased to two percent per year, declining to zero in the 1990s.[128]

At the same time, aquaculture production was rapidly increasing across North America, particularly production of brine shrimp, which was used as feed for other fish, and production of catfish in the Southern United States, with ample funding from the federal government.[129] Key to this growth was the development of plastics technology throughout the twentieth century, which made possible advanced life-support systems, tank complexes, and hatchery tanks, as well as the proliferation of scientific instruments.[130] Victor Loosanoff at the U.S. Bureau of Commercial Fisheries made huge advances in oyster cultivation during the middle of the twentieth century, salvaging the North American oyster industry and revitalizing the practice of oyster aquaculture, and successful salmon stations cropped up throughout the northern coastal states.[131] Shrimp farming emerged as a large industry in the southern United States after the pioneering efforts of the NMFS/NOAA Fisheries laboratory in Galveston, TX.[132] In 1971, Oregon passed the first law in the nation permitting ocean ranching of salmon, followed

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[128] *Id.*
[129] NASH, *supra* note 27, at 116–19.
[130] *Id.* at 128–29.
[131] *Id.* at 119–24. Victor Loosanoff wrote extensively on the subject of America's oysters. *See, e.g.*, VICTOR LOOSANOFF, U.S BUREAU OF COMMERCIAL FISHERIES, THE AMERICAN OR EASTERN OYSTER (1965); VICTOR LOOSANOFF & HARRY C. DAVIS, REARING OF BIVALVE MOLLUSKS (1963).
[132] NASH, *supra* note 27, at 135–36.

thereafter by other states including, most aggressively, Alaska.[133] However, the rapid expansion enjoyed by aquaculture between 1960 and 1970 coincided with high production costs that resulted in low yields and inefficiency, since the industry and its technology were still very young.[134]

During this time, the United States began extensively carrying out and funding marine science- and aquaculture-related projects. For example, Lyndon Johnson's Scientific Advisory Committee, created by the Marine Resources and Engineering Development Act of 1966,[135] "explor[ed] the resources of the sea through an intense national program of oceanographic and marine research," which culminated in the publication of a report entitled *Our Nation and the Sea: A Plan for National Action*, often referred to as the "Stratton Report" after its chief author Chairman Julius Stratton.[136] In 1966, Congress enacted the National Sea Grant College and Program Act of 1966, which was modeled after the United States' Land Grant Program to fund marine science and educational programs around the country.[137] Among the legislation's findings is the recognition:

> (c) that aquaculture, as with agriculture on land, and the gainful use of marine resources can substantially benefit the United States, and ultimately the people of the world, by providing greater economic opportunities, including expanded

[133] DON HORNSTEIN, SALMON RANCHING IN OREGON: STATE AND FEDERAL REGULATIONS, SPECIAL REPORT 573, 2 (1980); *see also* Emil R. Berg, *Private Ocean Ranching of Pacific Salmon and Fishery Management: A Problem of Federalism*, 12 ENVTL. L. 81 (1981) (discussing the origins of private ocean ranching permits in the United States and the federalism problems inherent therein); NASH, *supra* note 27, at 143.
[134] LADON SWANN, AQUACULTURE EXTENSION SPECIALIST, ILLINOIS-INDIANA SEA GRANT PROGRAM, A BASIC OVERVIEW OF AQUACULTURE 1 (1992).
[135] 33 U.S.C. § 1101 *et seq*. (1966).
[136] NASH, *supra* note 27, at 124; STRATTON COMMISSION ON MARINE SCIENCE, ENGINEERING, AND RESOURCES, OUR NATION AND THE SEA: A PLAN FOR NATIONAL ACTION (1969). The Stratton Report has been heralded as a "blueprint" for the "Blue Revolution." NASH, *supra* note 27, at 124.
[137] National Sea Grant College and Program Act of 1966, Pub L. No. 89-688 (1986). *See* OFFICE OF SEA GRANT, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL SEA GRANT COLLEGE PROGRAM: THE FIRST TEN YEARS 3–4 (1979) (describing the similarities and differences between the Land Grant Program and the Sea Grant Program).

> employment and commerce; the enjoyment and use of our marine resources; new sources of food; and new means for the development of marine resources . . . .[138]

With approval by the National Science Foundation, this funding could be used for a wide variety of projects, namely:

> for the education of participants in the various fields relating to the development of marine resources with preference given to research aimed at practices, techniques, and design of equipment applicable to the development of marine resources; encouraging and developing programs consisting of instruction, practical demonstrations, publications with the object of imparting useful information to persons currently employed or interested in the various fields related to the development of marine resources.[139]

The Sea Grant Program afforded substantial funding to marine science projects, including $7.1 million in grants as early as 1968 and $38.6 million in grants in 1976, and often would lead funded projects to additional funding by other grants.[140] In 1976 alone, $4.5 million went toward funding aquaculture projects.[141] According to the Office of Sea Grant's 1979 Ten Year Report, which devoted three full pages to a discussion of aquaculture projects funded under its program:

> The underlying thrust of Sea Grant-supported [aquaculture] efforts is *to increase the variety and profitability* of the species that can be farmed. To minimize the economic risk, initial emphasis has been on high value species though the long-term promise is one of large-volume production of low-cost sources of high-

[138] *Id.* § 202. The current National Sea Grant College Program legislation appears at 33 U.S.C. § 1121–1131 (2006). Curiously, the Congressional findings for the modern legislation omit any reference to aquaculture. *See id.* § 1121.
[139] This allowance was substantially broadened, even, by the legislation's definition of "marine resources" as:

> scientific endeavors relating to the marine environment, including but not limited to the fields oriented toward the development, conservation, or economic utilization of the physical, chemical, geological and biological resources of the marine environment, the fields of marine commerce and marine engineering, the fields relating to exploration or research in, the recover of natural resources from, and the transmission of energy in, the marine environment; the fields of oceanography and oceanology and the fields with respect to the study of the economic, legal, medical or sociological problems arising out of the management, use, development recovery and control of the natural resources of the marine environment.

National Sea Grant College and Program Act of 1966, Pub L. No. 89-688, § 202 (1986).
[140] OFFICE OF SEA GRANT, *supra* note 137, at 12–14 (1979).
[141] *Id.* at 15. This sum includes both federal dollars and other "matching" dollars that would be unavailable but for the initial federal grant. *Id.*

protein foods.[142]

The focus of this program insofar as it related to aquaculture, then, was not environmentally conscious aquaculture development. It was, simply, aquaculture development. Not surprisingly, aquaculture projects proliferated in the 1960s and 1970s as a result of this generous funding without much attention to the environmental consequences of increased operations.[143]

In one Sea Grant-funded project, a 1970 report entitled *Aquaculture and the Law*, Thomas Kane, a Masters of Laws candidate at the University of Miami, foretold the rise of aquaculture, emphasizing that because "[p]rojected population increases will result in severe food shortages for the world community . . . it is imperative that new food sources be located."[144] The marine environment, generally, and aquaculture, specifically, "hold promise as a new food source . . . ."[145] Kane's report contains a thorough examination of the scattered jurisdiction over aquaculture practice in the United States, the legal challenges and conflicting claims likely to arise if aquaculture practice were to proliferate throughout the United States, and several recommended courses of action to address substantial uncertainties in the regulatory framework for aquaculture.[146] But his warnings about patchwork jurisdiction and conflicts of interest, including the conflicts possible from environmental degradation caused by aquaculture,[147] remained largely unheeded.

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[142] *Id.* at 20 (emphasis added). The Report devotes three pages to a discussion of the aquaculture programs funded by Sea Grant. *Id.* at 20–23.
[143] OFFICE OF SEA GRANT, *supra* note 137, at 15 (1979); *see also* NASH, *supra* note 27, at 125.
[144] Kane, *supra* note 3, at 1.
[145] *Id.*
[146] *See generally id*. at 71. Kane often references Florida law throughout the Report, as his primary audience is made up of Florida regulators and aquaculturalists. But he encourages use of his Report by others, indicating that "this work is not intended as a survey of Florida law per se." *Id.* at 3.
[147] Kane, *supra* note 3, at 1.

Instead, aquaculture, fueled by government funding, launched full swing ahead. In 1970, pursuant to the recommendations of the Stratton Report and under President Nixon's supervision, NOAA was formed as a semi-autonomous agency in the Department of Commerce "for better protection of life and property from natural hazards . . . for a better understanding of the total environment . . . [and] for exploration and development leading to the intelligent use of our marine resources."[148] Soon thereafter, the private sector became cognizant of the substantial government funding for aquaculture technology and put substantial support behind the industry. Large corporations like Armor, United Brands, and Dow Chemical Corporation began backing shrimp harvest operations, which had the effect of moving many operations to South America where their other industries were located.[149] Other companies well-known companies like Raston Purina Company, General Mills Inc., Coca Cola Company, Walt Disney Productions, and the Wyerhauser Corporation became interested in various aquaculture sectors as well.[150] In 1976, the first state trade association for aquaculture, the Maine Aquaculture Association, developed in the United States to support local aquaculture development, with many cropping up shortly thereafter to encourage the booming industry.[151] The World Mariculture Society, which was formed in the 1960s and later renamed the World Aquaculture Society, had a membership of two thousand people spread over twenty countries by the 1970s.[152] Aquaculture consultants and written guidance on aquaculture operations proliferated worldwide, with trade journals like *Aquaculture*[153] and books like *Fish Hatchery Management*[154] and *Aquaculture: The Farming and*

[148] Reorganization Plan No. 4 of 1970, 5 U.S.C. App. (1970).
[149] NASH, *supra* note 27, at 146.
[150] *Id.*
[151] About MAA, Maine Aquaculture Association, http://www.maineaquaculture.com/About_MAA/about_maa.html (last visited Mar. 15, 2012).
[152] NASH, *supra* note 27, at 156–57.
[153] *See* Elselvier, Aquaculture, Celebrating 40 Years of Aquaculture, http://www.journals.elsevier.com/aquaculture/journal-news/celebrating-40-years-of-aquaculture/ (last visited Mar. 10, 2012); NASH, *supra* note 27, at 165.

Husbandry of Freshwater and Marine Organisms[155] entering the field, decreasing the cost of obtaining information to start and maintain aquaculture operations. Whereas between 1950 and 1969 aquaculture production grew by about five percent per year, during the 1970s it grew about eight percent per year.[156] Between 1971 and 1976, the industry enjoyed major production improvements and decreased costs as inefficient producers were driven out of the market when fishmeal became scarce, with average annual yields increasing from approximately 1,500 to 2,000 pounds per acre to 3,000 to 4,000 pounds per acre.[157]

Despite this boom in growth, however, some acknowledged that aquaculture had greater potential than had yet been realized. Echoing the warnings of Kane's Sea Grant paper, a 1981 report by the Aspen Research and Information Center determined that at least 120 federal statutory programs had a significant impact on development of aquaculture, but also found that fewer than half of those programs clearly required any compliance response from the impacted culturist.[158] Both the regulators and the regulated saw this mess of regulatory jurisdiction as a limit on realization of aquaculture's full potential, a minefield of uncertainty navigable only by the wealthiest corporations. In 1978, a National Research Council report stated the problem succinctly: "constraints on orderly development of aquaculture tend to be political and administrative, rather than scientific and technological . . . ."[159] "Aquaculture in the United States," the report warned, "has lacked coherent support and direction from the Federal

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[154] ROBERT G. PIPER, FISH HATCHERY MANAGEMENT (1986).
[155] JOHN E. BARDACH, JOHN H. RYTHER, & WILLIAM O. MCLARNEY, AQUACULTURE: THE FARMING AND HUSBANDRY OF FRESHWATER AND MARINE ORGANISMS (1972).
[156] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, THE STATE OF WORLD FISHERIES AND AQUACULTURE 3 (2000).
[157] Swann, *supra* note 134, at 1.
[158] ASPEN RESEARCH AND INFORMATION CENTER, AQUACULTURE IN THE UNITED STATES: REGULATORY CONSTRAINTS, REPORT TO THE U.S. FISH AND WILDLIFE SERV. (1981).
[159] NAT'L RESEARCH COUNCIL, AQUACULTURE IN THE UNITED STATES: CONSTRAINTS AND OPPORTUNITIES (1978); *see also* U.S. CONG., OFFICE OF TECH. ASSESSMENT, CURRENT STATUS OF FEDERAL INVOLVEMENT IN U.S. AQUACULTURE 4 TA-BP-ENV-170 (2005).

Government. Poor coordination, lack of leadership, and inadequate financial support have traditionally characterized programs relating to aquaculture."[160] These and other concerns fueled a push for legislation to clarify the regulatory field and to determine the course for the aquaculture industry in the United States in the coming decades.

At the end of his presidency, in response to such concerns, Jimmy Carter signed into law the National Aquaculture Act of 1980 ("NAA" or "the Act"), [161] the only legislation devoted specifically to aquaculture development in the United States. President Carter had "reluctantly" vetoed a similar bill in 1978 for lack of "adequate demonstration of need."[162] The House Report for the final enacted bill explained that since Carter had vetoed the 1978 Bill, "the administration [had] . . . conceded the wisdom of establishing a statutory mechanism to promote and coordinate federal aquaculture efforts but remain[ed] opposed to costly new programs until the need for such programs is clearly demonstrated."[163] Thus, the House added a robust new planning provision "under which the comprehensive information required in order to assess the need for federal support for aquaculture could be swiftly gathered and a national development plan formulated."[164] With this information-gathering tool, Carter felt comfortable signing the NAA into law.

President Carter announced upon signing the NAA that the legislation:

> formalizes the interagency coordinating mechanism which [was] working so well[;] . . . calls for the formulation of a long-range national aquaculture plan[;] . . . requires the development of strategies to meet the recommendations of the studies on financial and regulatory constraints[;] . . . and authorizes funds for

[160] NAT'L RESEARCH COUNCIL, *supra* note 159; *see also* CARL J. SINDERMANN, U.S. DEP'T OF COMMERCE, FOOD PRODUCTION FROM AQUATIC SPECIES: A PROGNOSIS FOR THE 1980'S, SHL80-06, 9–10 (1980).
[161] 16 U.S.C. §§ 2801–2810 (2006).
[162] Jimmy Carter, President, Statement on Signing S. 1650 National Aquaculture Act of 1980 Into Law (Sept. 26, 1980).
[163] National Aquaculture Act of 1980, H.R. Rep. No. 96-196(II) 7/2907 (July 16, 1979).
[164] *Id.*

> the support of research, development, and technology transfer by the Secretaries of Agriculture, Commerce, and Interior.[165]

He applauded the legislation for aiding "an expanded aquaculture industry [which] can help overcome a trade imbalance caused by the importation of some $2 billion of seafood each year," to realize the "considerable potential for expansion."[166] However, he explained that "aquaculture development is clearly the responsibility of the private sector," and he viewed the federal government's role as: "conducting and supporting research and in establishing, through a national plan, a framework for cooperation between Government and the private sector."[167]

True to President Carter's description, the Act provides that the private sector will bear primary responsibility for domestic development of the aquaculture industry[168] and requires the Secretaries of Agriculture, Commerce, and Interior to develop nonbinding aquaculture plans identifying species for aquaculture development and recommendations for how to increase production.[169] While the NAA does nod to environmental concerns, requiring that the secretaries "address" "water quality management" and "use of waste products" and "include . . . research programs on the effect of aquaculture on estuarine and other water areas and on the management of such areas for aquaculture," the Act omits any regulatory guidelines relating to environmental issues.[170] Instead of addressing environmental problems caused by aquaculture in meaningful way, the Act rather roots its support of aquaculture in the industry's environmental benefits, noting that "the harvest of certain species of fish and shellfish exceeds levels of optimum and sustained yield," and "aquacultural production . . . can assist in the control and abatement of

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[165] Jimmy Carter, President, Statement on Signing S. 1650 National Aquaculture Act of 1980 Into Law (Sept. 26, 1980).
[166] *Id.*
[167] *Id.*
[168] 16 U.S.C. § 2801(a)(6) (2006) ("The principal responsibility for the development of aquaculture in the United States must rest with the private sector.").
[169] *Id.* § 2803.
[170] *Id.* § 2803(b)(3)(B)–(C), (4).

pollution."[171] The main thrust of the Act, rather, is to declare aquaculture a national priority,[172] to clarify that the private sector should manage itself, to attempt to coordinate the disparate regulatory regimes through development of an interagency aquaculture coordinating group,[173] to conduct a variety of studies on aquaculture, industry regulation, and capital needs of the industry,[174] and to authorize appropriations to carry out the NAA.[175] Thus, the major piece of legislation affecting aquaculture in this country focuses on issues surrounding commercial viability and industry development, rather than environmental issues, ultimately viewing aquaculture as a solution to a tragedy of the commons, not the instigator of a tragedy of its own.

After passage of the NAA, the industry continued to follow a similarly rapid growth trajectory. Growth and efficiency gains steadily continued into the 1980s with a production growth rate of eight percent per year,[176] although the catfish industry saw decreased expansion.[177] Government funding for aquaculture operations increased with the 1985 Farm Bill, termed, in relevant part, the National Aquaculture Improvement Act of 1985.[178] Steady improvements in aquaculture technology, including the proliferation of net pens like the OpenSpar Sea Cage System and the Bridgewater platform, which could move offshore, away

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[171] *Id.* § 2802(a)(1), (4).
[172] *Id.* § 2801(c). The policy section provides:

> Congress declares that aquaculture has the potential for reducing the United States trade deficit in fisheries production, for augmenting existing commercial and recreational fisheries and for producing other renewable resources, thereby assisting the United States in meeting its future food needs and contributing to the solution of world resource problems. It is, therefore, in the national interest, and it is the national policy, to encourage the development of aquaculture in the United States.

Id.
[173] *Id.* § 2805.
[174] *Id.* §§ 2803(e), 2807, 2808.
[175] *Id.* § 2809.
[176] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, THE STATE OF WORLD FISHERIES AND AQUACULTURE 3 (2000).
[177] Swann, *supra* note 134, at 1.
[178] National Aquaculture Improvement Act of 1985, 7 U.S.C. § 1737 (1985).

from conflicting coastal uses.[179] Private sector aquaculture development began to realize economies of scale, with net pens increasing from one thousand to thirty thousand cubic meters in the pursuit of greater fish production in the minimum of space.[180] The United States Department of Agriculture reports that total weight of aquaculture production for ten of the most popular cultured species increased from 139,887 metric tons in 1983 to 313,518 metric tons in 1992.[181] The total value of aquaculture production in the United States rose by about 400 percent, to almost $1 billion, in the 1980s and 1990s.[182] Worldwide, in 1993 global aquaculture production represented 15 million tons out of a total harvest of 100 million tons.[183] In fact, aquaculture was so productive that, according to the FAO, increases in food fish production (including both aquaculture and capture fisheries) "of 20 million tonnes [between 1990 and 2000 were] mainly due to aquaculture, as capture fisheries production remained relatively stable."[184] Thus during the 1980s and 1990s, aquaculture continued its steady rise in the United States.

However, the industry was not without its limiting issues. In the 1990s, economies of scale quickly transformed into diseconomies of scale, as the close quarters of large aquaculture farms led to disease outbreaks within individual, and among neighboring, aquaculture facilities. This is the case because "crowding, temperature fluctuations, [and] inadequate dissolved oxygen" stress the species, weakening their natural defenses to disease, and crowding provides a means of quick transmission from fish to fish.[185] In fact, in the 1980s and 1990s, disease was the most

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[179] D.C.B. Scott & J.F. Muir, *Offshore Cage Systems—A Practical Overview*, 79, *in* OPTIONS MEDITERRANEENNES (J. Muir & B. Basurco eds. 2000); *see also* NASH, *supra* note 27, at 174–75.
[180] NASH, *supra* note 27, at 174.
[181] U.S. DEP'T OF AGRICULTURE, OVERVIEW OF AQUACULTURE IN THE UNITED STATES (Oct. 1995).
[182] U.S. Ocean Comm'n, *Setting A Course for Sustainable Marine Aquaculture*, *in* AN OCEAN BLUEPRINT FOR THE 21ST CENTURY 330 (2004).
[183] James R. Coull, *Will A Blue Revolution Follow the Green Revolution? The Modern Upsurge of Aquaculture*, 25 AREA 350 (1993).
[184] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, THE STATE OF WORLD FISHERIES AND AQUACULTURE 3 (2000).
[185] Fred P. Meyer, *Aquaculture Disease and Health Management*, 69 J. ANIM. SCI. 4202, 4202 (1991).

significant cause of economic losses incurred by fish farmers in the United States.[186] For example, in the 1990s, ninety five percent of a shrimp crop was lost due to outbreaks of the Taura Syndrome virus in Texas and South Carolina.[187] Industry-wide losses were also striking. For example, 115 million catfish were lost to disease during the first half of 1989, costing the industry a minimum of $8 million.[188] The environmental harms of aquaculture had begun to affect the industry's bottom line, creating a natural incentive to do something to minimize environmentally harmful practices, or to externalize environmental harms, for example, by locating facilities in a high-current area so down-current activities would bear the brunt of the effluent's effects. Another issue that potentially limited the full realization of aquaculture development in the United States was the presence of significant user conflicts in coastal areas. As described by the FAO, "much of the coastline of the United States of America is well developed and competition for space in the coastal and nearshore [sic] environment creates user group conflicts."[189]

In the United States, however, aquaculture's environmental and user-conflict problems were not at the top of the regulatory agenda, largely because aquaculture was still understandably seen as a solution to the ever-increasing problems of overexploitation of wild fish stocks, which, by 1995, were abundantly clear. In 1976, Congress passed the Magnuson Stevens Fishery

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[186] *Id.* ("Losses incurred by fish farmers are related to disease, floods, oxygen depletions, predation, chemical poisoning, theft, and miscellaneous causes. Disease is by far the most significant factor.").

[187] REBECCA GOLDBURG & TRACY TRIPLETT, THE ENVIRONMENTAL DEFENSE FUND, MURKY WATERS: ENVIRONMENTAL EFFECTS OF AQUACULTURE IN THE US 99, 141 (1995) (describing the outbreaks of the Taura syndrome virus in Texas and South Carolina and describing how microalgal outbreaks beside facilities can occur due to overconcentration of nitrogenous waste). In other countries, similarly devastating disease outbreaks occurred, serving as a warning to aquaculture industries in the United States. *See, e.g.*, Alexei Barrionuevo, *Salmon Virus Indicts Chile's Fishing Methods*, NY TIMES, Mar. 27, 2008 (noting the devastating outbreak of infectious salmon anemia resulting from the overconcentration in Chilean fish pens).

[188] Meyer, *supra* note 185, at 4202.

[189] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN NORTH AMERICA: CANADA AND THE UNITED STATES OF AMERICA, FISHERIES AND AQUACULTURE CIRCULAR NO. 1061/2, 2 (2010).

Conservation and Management Act of 1976,[190] which established NMFS/NOAA Fisheries jurisdiction over fisheries out to 200 nautical miles from shore.[191] The Purposes section of the Act acknowledges that:

> Certain stocks of fish have declined to the point where their survival is threatened, and other stocks of fish have been so substantially reduced in number that they could become similarly threatened as a consequence of (A) increased fishing pressure, (B) the inadequacy of fishery resource conservation and management practices and controls, or (C) direct and indirect habitat losses which have resulted in diminished capacity to support existing fishing levels.[192]

Thus, the purpose of the Act was "to take immediate action to conserve and manage the fishery resources found off the coasts of the United States . . . ."[193] This national preoccupation with solving the overfishing problem continued through the turn of the century, with major amendments occurring in 1996 under the Clinton administration[194] and in 2006 under the George W. Bush administration.[195] While the original Act had focused on phasing out foreign fishing, the 1996 amendments focused on rebuilding overexploited fisheries, protecting essential fish habitat, and reducing bycatch,[196] and the 2006 amendments similarly focused on ending overfishing by imposing Annual Catch Limits on fisheries subject to overfishing.[197]

This emphasis was justified in many respects by the staggering statistics on overfishing in the United States and abroad, with the harvest of overexploited fish stocks having dropped forty

[190] 16 U.S.C. §§ 1801–1884 (1976).
[191] *Id.* § 1801(b)(1).
[192] *Id.* § 1801(a)(2).
[193] *Id.* § 1801(b)(1).
[194] Sustainable Fisheries Act of 1996, Pub. L. No. 104-297 (1996).
[195] Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, Pub. L. No. 109-479 (2007).
[196] *See generally* Pub. L. No. 104-297 (1996).
[197] *See generally* Pub. L. No. 109-479 (2007); 16 U.S.C. § 1853(a)(15).

percent in the nine years preceding 1994.[198] In the United States, in the absence of national concern for aquaculture's negative effects, the aquaculture industry remained subject to scattered regulatory jurisdiction under an abundance of federal pollution control, fisheries management, and coastal use laws, which were primarily designed for other purposes, as well as state law analogues.[199]

Despite the salient, urgent plight of fisheries, on the global scale attention began to turn to environmental concerns resulting from aquaculture production. In 1992, following the International Conference on Sustainable Fishing, the United Nations Food and Agriculture Organization ("FAO") published a voluntary Code of Conduct for Responsible Fishing, wherein the FAO both promoted aquaculture and encouraged simultaneous environmental measures.[200] For example, the FAO stated that: "states should consider aquaculture, including culture-based fisheries, as a means to promote diversification of income and diet. In so doing, States should ensure that resources are used responsibly and adverse impacts on the environment and on local communities are minimized."[201] However, this voluntary call to action remained largely ignored in the United States.

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[198] R. Grainger & S. Garcia, *Chronicles of Marine Fishery Landings (1950-1994): Trend Analysis and Fisheries Potential*, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS FISHERIES TECHNICAL PAPER 359, 10–11, 31 (1996).

[199] For a necessarily brief discussion of some of the federal regulatory statutes applicable to aquaculture operations, see *infra* Part V. B. Complexity and Inadequacy of Current Regulatory Framework.

[200] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, CODE OF CONDUCT FOR RESPONSIBLE FISHERIES (1992).

[201] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, TECHNICAL GUIDELINES FOR RESPONSIBLE FISHERIES, AQUACULTURE DEVELOPMENT 3 (1997) (quoting FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, CODE OF CONDUCT FOR RESPONSIBLE FISHERIES Art. 6.19, (1992)). The Code of Conduct for Responsible Fisheries demonstrates clear concern for environmental issues in several additional provisions:

> **6.1** States and users of living aquatic resources should conserve aquatic ecosystems.
> **6.8** All critical fisheries habitats in marine and fresh water ecosystems, such as wetlands, mangroves, reefs, lagoons, nursery and spawning areas, should be protected and rehabilitated as far as possible and where necessary. Particular effort should be made to protect such habitats from

Even though a clear, environmentally effective regulatory structure is lacking, the aquaculture industry has continued to flourish into the twenty first century, with aquaculture production increasing to 644,213 tons in 2008 from 536,169 tons in 1998.[202] But because the environmental and coastal conflict issues discussed above still stand as impediments to realization of aquaculture's full potential, much attention has been paid to the promise of moving aquaculture farther offshore,[203] into the United States Exclusive Economic Zone ("U.S. EEZ").[204] Congressional recognition of the issues of near-shore aquaculture, and the potential solution in open ocean aquaculture, came in the form of several proposed Bills: H.R. 2010, the National Offshore Aquaculture Act of 2007,[205] H.R. 4363, the National Sustainable Offshore Aquaculture Act of 2009,[206] and H.R. 2373, the National Sustainable Offshore Aquaculture Act of 2011,[207] the former of which was sponsored by Representative Nick Rahall, a Republican Congressman from West Virginia, and the latter two of which were sponsored by Representative Lois Capps, a Democratic Congresswoman from California. These bills, all of which remained

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> destruction, degradation, pollution and other significant impacts resulting from human activities that threaten the health and viability of the fishery resources.
> **6.7** The harvesting, handling, processing and distribution of fish and fishery products should be carried out in a manner which will maintain the nutritional value, quality and safety of the products, reduce waste and minimize negative impacts on the environment.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS ARTS. 6.1, 6.7 & 6.8 (1992).

[202] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN NORTH AMERICA: CANADA AND THE UNITED STATES OF AMERICA, FISHERIES AND AQUACULTURE CIRCULAR NO. 1061/2, 2 (2010). This trend had occurred worldwide, with a vote of confidence from the World Bank, which, as of 2007, had invested over one billion dollars in aquaculture projects. THE WORLD BANK, *supra* note 4, at 2.

[203] The Congressional Research Service has noted that"[p]roponents of open ocean aquaculture suggest that open ocean finfish aquaculture systems may produce fewer and less severe environmental impacts than those caused by nearshore [sic] aquaculture systems." *See generally*, HAROLD F. UPTON & EUGENE H. BUCK, CONG. RESEARCH SERV., RL 32694, OPEN OCEAN AQUACULTURE 11 (June 12, 2008).

[204] The U.S. EEZ is the area of the ocean located between three and two hundred nautical miles offshore. DAVID HUNTER, JAMES SALZMAN, & DURWOOD ZAELKE, INTERNATIONAL ENVIRONMENTAL LAW AND POLICY 747 (4th ed. 2011). The United Nations Convention on the Law of the Sea established that coastal states have the sovereign right to explore, exploit and manage the resources within their EEZ. *Id.*

[205] H.R. 2010, 110th Cong. (2007).

[206] H.R. 4363, 111th Cong. (2009).

[207] H.R. 2373, 112th Cong. (2011).

stagnant in Committee, contain multiple environmental requirements, though the latter two differ substantially in substance from the former. These requirements include coordinated federal permitting requirements,[208] regional programmatic environmental impact statements,[209] and liability provisions for natural resources damages.[210] The latter two bills also encourage adherence to the Code of Conduct for Responsible Fisheries.[211] They would create an Office of Sustainable Offshore Aquaculture and "guide the precautionary development of offshore aquaculture in the [EEZ] that ensures ecological sustainability and compatibility with healthy, functional ecosystems."[212] However, as with many legislative efforts of the last several years, these bills have been abandoned in committee, and aquaculture remains a flourishing, yet partially unrealized, source of domestic fish protein.

The history of aquaculture is a complex, inspirational, yet cautionary tale of the ebbs and flows of an American industry. The industry became popular at various points throughout several millennia to serve different purposes, but was often most valued as a means providing fish protein in inland areas and, more recently, became a means of acquiring fish protein as a general matter, to substitute for product from dwindling capture fisheries. Conceptualized as a solution to other environmental problems, modern aquaculture has not been viewed as an independent source of problems of its own, thus resulting in the fractured regulatory structure discussed in more detail below. Having traced the history of the industry, this Paper now turns to a brief description of the benefits and costs of modern aquaculture, and then assesses present and

[208] *See, e.g.*, H.R. 2010, 110th Cong., § 4 (2007); H.R. 4363, 111th Cong., § 5 (2009); H.R. 2373, 112th Cong., § 5 (2011).
[209] *See, e.g.*, H.R. 4363, 111th Cong., § 4 (2009); H.R. 2373, 112th Cong., § 4 (2011).
[210] *See, e.g.*, H.R. 4363, 111th Cong., § 12 (2009); H.R. 2373, 112th Cong., § 12 (2011).
[211] *See, e.g.*, H.R. 4363, 111th Cong., § 13 (2009); H.R. 2373, 112th Cong., § 13 (2011).
[212] *See, e.g.*, H.R. 4363, 111th Cong., §§ 2(4), 3(a)(1) (2009); H.R. 2373, 112th Cong., §§ 2(4), 3(a)(1) (2011).

future challenges faced by the industry and the inadequacy of the modern regulatory structure to handle those challenges.

IV. The Benefits and Harms of Modern Aquaculture

Before delving into an account of the present state and future challenges of aquaculture in the United States in Part V, this Part pauses to briefly summarize the benefits and harms of the modern aquaculture industry. This Part aims to give the reader a sense of the reasons aquaculture has, in may respects justifiably, become popular as an environmentally sustainable source for fish in modern times, and the ways in which its popularity may forecast significant deterioration to the environment and may ultimately threaten the industry's commercial viability.

A. Benefits of Farm-Raised Fish

The sharp rise in popularity of aquaculture is in many ways well founded because of the significant benefits the industry has over capture fisheries and terrestrial sources of protein. The benefits of farm-raised fish are abundant from both nutritional and environmental perspectives.

i. Nutritional Benefits

Aquaculture has the potential to afford substantial nutritional benefits to society by facilitating access to fish, providing fresher and thus more nutritious fish, and providing an inherently healthier product through manipulation of fish environments throughout the aquaculture production process.

Because aquaculture may be practiced in areas where fisheries are absent or dwindling, such as poor inland areas and overfished coastal areas, aquaculture can provide fish protein to communities who would otherwise have none. Access to aquaculture products can provide

substantial, stable nutritional benefits to inland communities, as fish contain large resources of protein, and many readily available amino acids, in comparable quantities to terrestrial protein sources like meat and milk, such as lysine, methionine, and tryptophan.[213] Nash goes so far as to claim that "[w]ith their unsaturated fats, minerals, and trace elements, all equally important to the human diet, fish and shellfish are considered to be almost as beneficial to the body as mother's milk."[214] In fact, fish may be healthier in many respects than terrestrial food sources, as fish oils have more polyunsaturated components than animal fats and can help to reduce the buildup of cholesterol in blood.[215] The high content of n-3 polyunsaturated fatty acids contained in aquaculture products are thought to prevent cardiovascular diseases and cancers.[216] Even when aquaculture facilities are not located nearby, aquaculture product can often be shipped to inland "food deserts" more cheaply, as farmed fish are generally uniform in size so no sorting is required to harvest and ship the product to processors, standard box sizes may be used, and processing steps may be automated by using machines instead of manual labor.[217] Moreover, fish from aquaculture facilities are sold on the fresh fish markets more often than their wild-caught counterparts.[218] Only a third of wild-caught fish are sold as fresh products, with the remainder two thirds "preserved in some way in cans or bottles, or reduced into commercial fish meals and oils."[219]

Moreover, aquaculture products can be inherently more healthful than product from capture fisheries because aquaculture facilities can control the quantity and quality of feed the

[213] NASH, *supra* note 27, at 6.
[214] *Id.* at 6.
[215] *Id.* at 7.
[216] B. Fauconneau, *Health Value and Safety Quality of Aquaculture Products*, 153 REVUE MÉD. VÉT., 331, 332 (2002).
[217] NASH, *supra* note 27, at 8.
[218] *Id.* at 8.
[219] *Id.*

fish receive, which affects the fat content, flavoring, and the color of fish products.[220] Finally, aquaculture facilities, especially closed-cycle facilities, can often control exposure of cultured fish populations to toxins like mercury, which is one of the most problematic aspects of fish consumption.[221] Thus, aquaculture has substantial nutritional benefits that are potentially more significant than product from capture fisheries.

ii. Environmental Benefits

The potential environmental benefits of aquaculture are substantial, and account in large part for the surge in popularity of the industry, as delineated above. The most obvious benefit is that sustainably farmed aquaculture product can reduce demand for product from capture fisheries. In the United States, as discussed above, overfishing has become a large problem; according to the Pew Commission in 2001 30.6 percent of known wild fish stocks are experiencing overfishing or are overfished.[222] To the extent that aquaculture is performed in a sustainable manner, as discussed below, it can ease pressure on wild fish stocks by continuing to supply product to satisfy a large percentage of U.S. demand for fish. Moreover, aquaculture can help natural fish populations by providing habitat for natural species in artificial wetlands created by aquaculture activities, by producing eggs, fry, and juveniles to enhance fish stocks, and by preserving biodiversity through stock-raising programs.[223]

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[220] While flavoring or color may not initially seem to have nutritional implications, there is much research to suggest that altering such attributes can encourage consumption of specific food items. *See, e.g.*, Leann L. Birch, *Psychological Influences on the Childhood Diet*, 142 J. OF NUTRITION 407S (1998). Thus, encouraging consumption of certain nutritionally beneficial foods by manipulating taste and color can ensure provision of nutritional benefits. However, controlling the input of food can also have negative impacts, as discussed below, as the input of beneficial contents necessarily depends on the good faith of the facility manager.

[221] B. Fauconneau, *supra* note 216, at 333 ("Methyl-mercury accumulated in aquatic food chain and high mercury level are detected in fish and especially in fish fillets."); *see also* NASH, *supra* note 27, at 8.

[222] PEW OCEANS COMM'N, AMERICA'S LIVING OCEANS: CHARTING A COURSE FOR SEA CHANGE 37 Fig. 1 (2003).

[223] JOINT SUBCOMMITTEE ON AQUACULTURE, NATIONAL SCIENCE AND TECHNOLOGY COUNCIL DRAFT NATIONAL AQUACULTURE DEVELOPMENT PLAN § 4.1 (1996).

Aquaculture production also has several other substantial environmental benefits relative to other food sources. Aquaculture wastes, if handled properly, can be recycled as nutrient-dense fertilizer for agricultural products, hydroponic operations, or natural or constructed wetlands, thereby reducing the need for petroleum-based fertilizer.[224] Aquaculture operations can recycle wastes from other industries, like the agriculture and capture fisheries, by using those wastes in their feeds.[225] Aquaculture can benefit from heat waste from industrial plants[226] and can even feed off of and cleanse human wastes. For example, fish farms in Calcutta "feed on the 600 million litres of raw sewage that spews from [the city] every day, turning a health risk into a valuable urban crop."[227] According to the World Watch Institute, "[t]he restorative potential of fish farming is vast and . . . can be harnessed to multiply eelgrass beds, mangrove seedlings, and other lost ecosystems."[228] Moreover, some nutrient effluent is actually beneficial to benthic communities, and excessive nutrient effluent can be counteracted if the fish farm facilities coexist with shellfish or seaweed culture operations, which remove nutrients from surrounding waters.[229] These substantial environmental benefits make aquaculture seem like an obvious choice, especially when the alternative source of protein would be from overfished wild stocks or poorly treated, environmentally harmful livestock.[230] However, nearly all of the benefits delineated above require good faith planning, monitoring, and operation on the part of facility owners and operators with an eye toward maintaining sustainable, environmentally friendly

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[224] *Id.*
[225] *Id.* ("Conversely, aquaculture can take advantage of societal 'waste' materials. Agricultural and fisheries processing wastes can be incorporated into aquaculture feeds; nutrients from manures can stimulate primary productivity in aquaculture systems . . . .").
[226] JOINT SUBCOMMITTEE ON AQUACULTURE, NATIONAL SCIENCE AND TECHNOLOGY COUNCIL DRAFT NATIONAL AQUACULTURE DEVELOPMENT PLAN § 4.1 (1996).
[227] *See,* BRIAN HALWEIL, WORLD WATCH INSTITUTE, FARMING FISH FOR THE FUTURE 25–26 (2008).
[228] *Id.*
[229] Barry T. Hargrave, William Silvert, & Paul D. Keizer, *Assessing and Managing Environmental Risks Associated with Marine Finfish Aquaculture*, *5* ENV. CHEM. 433, 434 (2005).
[230] *See generally* U.S. DEP'T OF AGRICULTURE, U.S. SUMMARY AND STATE REPORTS: 2007 CENSUS OF AGRICULTURE, 1 GEOG. AREA SUMMARIES 51 (2009).

facilities; as the next section describes, though, environmentally conscious aquaculture operation is far from the norm.

B. Costs of Farm-Raised Fish

Although aquaculture became popular as a means of providing an *alternative* to environmentally harmful fishing practices, modern aquaculture practice itself causes substantial environmental problems, contributing to tragedies of both pollution and exploitation. This Section focuses primarily on the environmental degradation caused by modern aquaculture, though it is important to note that these environmental issues have significant effects on public health and economic welfare nationwide. As noted by the World Bank, "[t]he challenge of sustainable aquaculture is to contribute to national objectives for economic, development and food security while simultaneously addressing poverty reduction and environmental protection."[231] This Section demonstrates that effluent discharges from marine aquaculture facilities contribute to many environmental harms,[232] including "[i]mpacts on water quality, the benthic layer, the native gene pool, other fisheries, and the ecosystem as a whole, as well as impacts from non-native species, disease, and chemicals."[233] Moreover, paradoxically, aquaculture operations contribute to the tragedy of the commons by exploitation of wild fish stocks.

First, aquaculture can, and should, be conceptualized as a cause of a tragedy of the commons by pollution.[234] The most salient environmental harm caused by aquaculture in open

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[231] THE WORLD BANK, CHANGING THE FACE OF THE WATERS: THE PROMISE AND CHALLENGE OF SUSTAINABLE AQUACULTURE 2 (2007).
[232] *See* PEW OCEANS COMMISSION, SUSTAINABLE MARINE AQUACULTURE: FULFILLING THE PROMISE; MANAGING THE RISKS 6 (Jan. 2007) (describing environmental harms from aquaculture); Jansen Andermen-Hahn, *Net Pens with Adaptive Management: How to Manage the Expansion of Aquaculture Using the Clean Water Act*, 30 VT. L. REV. 1007, 1012-20 (Summer 2006) (summarizing environmental harms associated with aquaculture operations).
[233] BILIANA CICIN-SAIN, ET AL., UNIVERSITY OF DELAWARE, DEVELOPMENT OF A POLICY FRAMEWORK FOR OFFSHORE MARINE AQUACULTURE IN THE 3-200 MILE U.S. OCEAN ZONE 18 (2001).
[234] Hardin, *supra* note 9, at 1245.

aquatic and marine environments is impaired water quality in areas surrounding aquaculture facilities. Impairment results from effluent of nutrients from aquaculture facilities, which causes sediment organic enrichment and algae blooms, which in turn result in dissolved oxygen depletion, called eutrophication or "dead zones."[235] This waste can accumulate quickly and cause hazardous conditions, "contaminating surrounding areas and preventing sustainable life."[236]

Moreover, aquaculture facilities discharge many potentially harmful hazardous and nonhazardous chemicals into the ocean, including pesticides, hormones, antibiotics, parasiticides, pigments, vitamins, minerals and anesthetics.[237] The release of antibiotics into aquatic and marine environments is particularly worrisome. Antibiotics are used by aquaculture facilities to suppress disease and encourage rapid product growth.[238] In the United States the Food and Drug Administration ("FDA") has approved five drugs for treating, but not preventing, fish diseases.[239] The main risks of use of antibiotics in open aquaculture facilities is "related to their release in the environment," which "could induce the contamination of aquatic organisms" and, most notably, contribute to the growing problem of antibiotic resistance.[240] The chemical additives often used in fish farms to increase farm output and to keep cages clean, including chlorine, sodium hydroxide, iodophors, and calcium oxide, may also be disruptive to marine ecosystems.[241] Of course, the severity of these effects depends on complex factors such as "the technique applied, site location,

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[235] REBECCA GOLDBURG ET AL., MARINE AQUACULTURE IN THE UNITED STATES: ENVIRONMENTAL IMPACTS AND POLICY OPTIONS 13-14 (2001); Hargrave, *supra* note 229, at 436.
[236] MARK ARSENAULT, THOMAS BEIGBEDER, NATHAN JOHNSON, & KEVIN PEARCE, CURRENT AND FUTURE REGULATION OF MARINE AQUACULTURE, APP. H (2002).
[237] GOLDBURG ET AL., *supra* note 235, AT 13–14. These chemicals are harmful not only to marine life, but also to handlers and humans who eat marine life or are otherwise exposed to these chemicals. *Id.* at 15, Figure 6; *see also* Hargrave, *supra* note 229, at 436.
[238] ARSENAULT, BEIGBEDER, JOHNSON, & PEARCE, *supra* note 236, at App. H.
[239] U.S. GOV'T ACCOUNTABILITY OFFICE, GAO 11-286, FDA NEEDS TO IMPROVE OVERSIGHT OF IMPORTED SEAFOOD AND BETTER LEVERAGE LIMITED RESOURCES 8 (2011); ARSENAULT, BEIGBEDER, JOHNSON, & PEARCE, *supra* note 236, at App. H.
[240] B. Fauconneau, *supra* note 216, at 335; Hargrave, *supra* note 229, at 436.
[241] ARSENAULT, BEIGBEDER, JOHNSON, & PEARCE, *supra* note 236, at APP. H.

size of the production, capacity of the receiving body of water, and type of species raised," but the impacts have been felt throughout U.S. coastal areas. [242]

Another serious environmental problem caused by the aquaculture industry is genetic change in indigenous fish populations due to interbreeding with escaped farm fish. [243] Farm-raised fish are often different in genetic make-up than the natural populations of fish that live in nearby or contiguous waters, because fish in aquaculture facilities often interbreed and aquaculture operators often selectively breed fish to produce a better product.[244] This means that the "inevitable escape" of fish can result in degradation of the natural species, if the escaped fish are able to breed with the natural populations.[245] By one account, as many as forty percent of Atlantic Salmon caught in the North Atlantic originated on fish farms.[246] The development of genetically modified fish may make this issue even more serious. Even though the genetically modified fish currently under review by the FDA, the AquAdvantage® Salmon, is designed to be sterile, the effective sterility rate is not quite 100%, leaving room for a "Trojan fish" to infiltrate natural populations if ever released into aquatic or marine environments.[247]

Apart from genetic transmission, improperly operated and maintained aquaculture facilities may also cause disease and parasite (sea lice) transmission between wild and domestic

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[242] BILIANA CICIN-SAIN, ET AL., UNIVERSITY OF DELAWARE, DEVELOPMENT OF A POLICY FRAMEWORK FOR OFFSHORE MARINE AQUACULTURE IN THE 3-200 MILE U.S. OCEAN ZONE 18 (2001), *available at* http://www.whoi.edu/cms/files/kjoyce/2005/8/aquaculture_report_4624.pdf.
[243] Hargrave, *supra* note 229, at 435.
[244] ARSENAULT, BEIGBEDER, JOHNSON, & PEARCE, *supra* note 236, at APP. H.
[245] *Id.*
[246] P. Hansen, J.A. Jacobsen, & R.A. Und, *High Numbers of Farmed Atlantic Salmon,* Salmo salar, *Observed in Oceanic Waters North of the Faroe Islands*, 24 AQUACULTURE FISHERIES MGMT. 777, 777–81 (1993).
[247] *See* AQUA BOUNTY TECHNOLOGIES, INC., ENVIRONMENTAL ASSESSMENT FOR AQUADVANTAGE® SALMON: AN ATLANTIC SALMON (SALMO SALAR L.) BEARING A SINGLE COPY OF THE STABLY INTEGRATED **A**-FORM OF THE OPAFP-GHC2 GENE CONSTRUCT AT THE **A**-LOCUS IN THE EO-1**A** LINE 13 (Aug. 25, 2010) ("Triploidy is induced in fin-fish to inhibit their sexual development and render them sterile; and, pressure shock has exhibited an average efficiency exceeding 99% in inducing triploidy in AAS eggs at commercial scale. While the vast majority of AAS being cultured for retail sale will have no reproductive capacity, triploidy is not necessarily 100% effective in producing infertility . . . and reference to "sterile" AAS in this document should be interpreted in that context.").

populations because "crowding, temperature fluctuations, [and] inadequate dissolved oxygen" stress the species, weakening their natural defenses to disease.[248] Outbreaks of diseases and parasites have occurred in this country and abroad, with devastating effects on both culture and wild fish populations,[249] raising serious economic, environmental, and animal welfare concerns.[250] Pollution of the product itself can also be a problem. For example, many farmed fish are carnivorous and eat smaller, wild-caught fish. The fish meal and fish oils in feed used on fish farms for carnivorous fish like salmon is made of fish from the open sea and thus often contain contaminants like persisting organic pollutants, polycyclic aromatic hydro-carbons, and heavy metals like mercury as these toxins accumulate in the natural aquatic or marine food webs.[251] Thus, "aquaculture could be considered as a further step of accumulation of environmental contaminants compared to wild products," eliminating one of the most important nutritional benefits of aquaculture over wild-caught fish: the absence of heavy metals.[252] Moreover, use of fertilizers recycled from other industries, like chicken manure, can contaminate aquaculture product with pathogens like salmonella.[253] Thus, aquaculture operations can be a source of serious degradation of local, regional, and national environmental and public health commons by *pollution*.

Second, aquaculture can, and should, be conceptualized as a contributor to the tragedy of the commons by exploitation.[254] While aquaculture arose in part to ameliorate overfishing, it has, ironically, begun to contribute to the problem because many of the most in-demand aquaculture

[248] Hargrave, *supra* note 229, at 435; *see also* Meyer, *supra* note 185, at 4202.
[249] *See* discussion *supra* note 187; *see also* Hargrave, *supra* note 229, at 436.
[250] Hargrave, *supra* note 229, at 435.
[251] B. Fauconneau, *supra* note 216, at 334.
[252] *Id.*
[253] E. Spencer Garrett et al., *Public, Animal, and Environmental Health Implications of Aquaculture*, 3 EMERGING INFECTIOUS DIS. 453, 454 (1997).
[254] *See* Gordon, *supra* note 10, at 124–42; Hardin, *supra* note 9, at 1245.

products are carnivorous fish.[255] Catching fish to raise fish not only contributes to the pollution problems described above, but also contributes to the exploitation problems of capture fisheries.[256] In fact, many commercial aquaculture systems use two to five times more fish protein to feed the farmed species than is supplied by the farmed fish at the end of the aquaculture production cycle.[257] While some argue that farmed fish production is still more efficient than the production of carnivorous species in the wild, it is still the case that modern aquaculture still does not wholly solve the exploitation problem.[258] Moreover, habitat modification caused by siting of aquaculture facilities, including destruction of mangrove spawning habitats, has contributed to the depletion of wild fish stocks, and aquaculture operations often stock facilities with wild-caught fry, rather than cultured fry, removing those fish from the wild and resulting in discard of large amounts of wild bycatch.[259]

Thus, aquaculture has become a tragedy of the commons in many respects. Aquaculture has polluted coastal commons at the local, regional, national, and global scales through effluent of nutrients and a variety of chemicals and through genetic and disease transmission. It has also, somewhat paradoxically, exploited the global marine commons through fishing for feed and fry, as well as habitat modification for aquaculture siting. As the industry moves into the twenty first century, it must acknowledge and act to mitigate its contribution to problems of pollution and

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[255] Rosamond L. Naylor et al., *Effect of Aquaculture on World Fish Supplies,* 405 NATURE 1017, 1018 (2000).
[256] This problem has recently been a national news story, as the New York Times reported in April 2012 that marine scientists are "calling for cuts in commercial fishing for sardines, herring and other so-called forage fish whose use as food for fish farms is soaring." Henry Fountain, Too Many Small Fish Are Caught, Report Says, NY TIMES, http://www.nytimes.com/2012/04/02/science/earth/forage-fish-catches-should-be-reduced-report-says.html?_r=1&hpw (last visited April 2, 2012). The Report cited by the New York Times recommends cutting forage fishing by half to sustain predators and forage populations. LENFEST FORAGE FISH TASK FORCE & INSTITUTE FOR OCEAN CONSERVATION SCIENCE, LITTLE FISH BIG IMPACT 6 (2012).
[257] Naylor, *supra* note 255, at 1018.
[258] *Id.* at 1019.
[259] *Id.* at 1020–21 ("If bycatch rates are high, collecting seedstock for aquaculture operations can have very large consequences for wild fisheries.").

exploitation so that it can realize its full potential as both an independent, commercially viable industry and a solution to the increasing problem of overfishing worldwide.

V. Present and Future of Aquaculture in the United States

The present status of aquaculture is at once cause for hope and for concern. The aquaculture industry in large part arose to address the problems of one type of tragedy of the commons, exploitation in the form of overfishing,[260] and has arguably been successful in mitigating this tragedy in some areas of the world. However, aquaculture itself has quickly led to tragedies of the commons by pollution in the form of various types effluent to inland and marine water bodies and, further, by exploitation of wild fish populations for fish feed and facility siting.[261] Unfortunately, without proper regulation, aquaculture is doomed to create a new set of complex problems as it seeks to mitigate others. While the detrimental environmental impacts of foreign fish farming may justify the expansion of the U.S. industry, where environmental protections could be greater, it is still crucial to steer aquaculture away from likely tragedies of the commons to protect the regional commons of our inland water bodies and coasts.[262] This Part briefly describes the current and predicted future trends and challenges of aquaculture production and the complexity and inadequacy of the current regulatory framework for aquaculture production in the United States in light of these trends and challenges.

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[260] *See* Gordon*, supra* note 10, at 124–42; Hardin, *supra* note 9, at 1245; Berkes, *supra* note 19, at 199–206.
[261] *See* Hardin, *supra* note 9, at 1245; *Brooke Glass-O'Shea*, *Watery Grave: Why International and Domestic Lawmakers Need To Do More To Protect Oceanic Species from Extinction*, 17 HASTINGS W.-N.W. J. ENVTL. L. & POL'Y 191, 209–212 (2011) (describing the environmental degradation caused by marine pollution).
[262] *See, e.g.,* John Connelly, President, Nat'l Fisheries Inst., Address at the NOAA 2007 Nat'l Marine Aquaculture Summit, 14 (June 27, 2007), *available at* http://aquaculture2007.noaa.gov/pdf/transcript62707.pdf; *Offshore Aquaculture: Hearing Before the Subcomm. on Nat'l Ocean Policy Study of the S. Commerce Comm.*, 109th Cong. (2006) (statement of Sebastian Belle, Dir. Maine Aquaculture Ass'n); Thomas R. Head, III, *Fishy Business – Regulating Aquaculture Operations in the United States*, 18 NAT. RESOURCES & ENVT. 21, 21 (2004).

A. Present and Future Trends and Challenges in Aquaculture Development

Aquaculture has become a blue revolution: its growth has wildly exceeded industry and consumer expectations. In the 1990s, forward projections "look[ed] to global totals of production from aquaculture reaching as much as 50 million tonnes within another 25 years," in other words, by approximately 2020.[263] By 2010, however, 115 million tons of fish were used as human food, with aquaculture accounting for forty six percent, or 52.9 million tons, of aquaculture production.[264] Thus, by 2012, aquaculture production had already exceeded growth levels expected for the following decade. Similarly, K.M. Brander, in his 2004 article in the *Proceedings of the National Academy of Sciences* predicted that whereas sixty eight percent of production of fish, crustaceans, and mollusks in 2004 came from capture fisheries and the remaining thirty two percent came from aquaculture, "[a]quaculture production is rising rapidly, and by 2030 it is estimated that aquaculture production will be close to that of capture production."[265] In 2011, just seven years later, the FAO made a stunning announcement: "by 2012 more than 50 percent of global food fish consumption will originate from aquaculture."[266] Thus, aquaculture has experienced dramatic increases, exceeding most expectations, in the last several decades.

[263] Coull, *supra* note 183, at 350.
[264] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, THE STATE OF THE WORLD FISHERIES AND AQUACULTURE 3 (2010). According to the FAO, global aquaculture production actually reached 52.5 million tonnes in 2008. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, WORLD AQUACULTURE 2010 xi, 3 (2010) (describing generally the marked positive trends in aquaculture production over the last few decades and noting that "[a]quaculture remains a growing, vibrant and important production sector for high-protein food").
[265] K.M. Brander, Global Fish Production and Climate Change, 104 PROCEEDINGS OF THE NATL. ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA 19,709 (2007).
[266] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, WORLD AQUACULTURE 2010 xi (2011).

In the United States, specifically, marine aquaculture now occurs in every coastal state.[267] However, imports satisfy the ever-increasing domestic demand for seafood.[268] According to the FAO, the United States ranks 13th in total aquaculture production behind China, India, Vietnam, Indonesia, Thailand, Bangladesh, Norway, Chile, Philippines, Japan, Egypt, and Myanmar.[269] The United States' domestic shortage poses a threat to the nation's food security and increases the nation's dependence on foreign natural resources.[270] It is also a problem for the environment, as many other nations have far less stringent environmental regulation than the United States' patchwork of regulatory efforts.

Predicted trends for aquaculture in the United States are highly variable, but generally assume that the industry will continue to meet growing demand for seafood products.[271] The reasons for this predicted expansion are multiple. The U.S. population is expected to grow by fifty-two million people by 2025, with seafood demand expected to rise by 416,000 tons or more, given recent pressure from the FDA on the public to consume more fish products because of the health benefits associated with fish consumption.[272] This demand will have to be filled by aquaculture because global capture fisheries, the majority of which are currently fully exploited

[267] NOAA, Aquaculture in the United States, http://www.nmfs.noaa.gov/aquaculture/aquaculture_in_us.html (last visited Mar. 11, 2012).
[268] *See generally* Fish Watch, U.S. Seafood Facts, NOAA & National Marine Fisheries Service, http://www.nmfs.noaa.gov/fishwatch/trade_and_aquaculture.htm (last visited Nov. 12, 2010).
[269] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, THE STATE OF WORLD FISHERIES AND AQUACULTURE 2010 22 (2010).
[270] NOAA reports that "the U.S. seafood trade deficit has grown to over $10.4 billion annually—second only to oil in the natural resources category." NOAA, Aquaculture in the United States, http://www.nmfs.noaa.gov/aquaculture/aquaculture_in_us.html (last visited Mar. 11, 2012).
[271] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN NORTH AMERICA: CANADA AND THE UNITED STATES OF AMERICA, FISHERIES AND AQUACULTURE CIRCULAR NO. 1061/2, 2 (2010).
[272] *Id.* at 1.

or overexploited,[273] are expected to continue their steady decline, both because of natural oscillations in ecosystem productivity[274] and because of unsustainable overfishing of wild fish stocks.[275] The looming threat of climate change may also pose problems for the future of wild fish stocks and capture fisheries.[276] Climate change may cause displacement of ecosystem boundaries, alteration of species composition, ocean warming and acidification, increased eutrophication from flooding, major storm events, and introduction of new diseases, though the precise impacts are virtually impossible to calculate.[277] Thus, aquaculture is expected to continue its trend of growth to satisfy consumer demand for fish products in the face of decreased productivity and abundance of wild capture fisheries.

However, the otherwise bright future of aquaculture in this country may be tempered by several challenges. As noted above, the U.S. is competing with other nations to meet this demand for seafood and may struggle to reduce operating costs to compete with importers given relative land values and regulatory hurdles.[278] Moreover, the industry's technology is developing rapidly, facilitating aquaculture's expansion into new areas that carry a lot of uncertainty. For example, the recent invention of genetically modified fish that grow faster and better resist disease may launch a robust new inland aquaculture industry and may undermine coastal operations. However, it is

[273] Brander, *supra* note 265, at 19709. The capture production worldwide, excluding China, has decreased by approximately 233,000 tons between 1989 and 2007. *Id.* at 19710. It is estimated that at least seventy percent of world fish stocks are fully exploited, overexploited, or recovering from a period of depletion. *Id.*
[274] Serge M. Garcia & Richard J.R. Grainger, *Gloom and Doom? The Future of Marine Capture Fisheries*, 360 PHIL. TRANS. R. SOC. B 21 (2005).
[275] Garcia & Grainger, *supra* note 274, at 23.
[276] *Id.* at 22 ("Longer-term climate change will affect the ocean environment and its capacity to sustain fish stocks and is likely to exacerbate the stresses on marine fish stocks, from fishing and other marine or land-based activities."); Brander, *supra* note 265, at 19,709. These impacts are closely tied to the effects of fishing, as "fishing reduces the age, size, and geographic diversity of populations and the biodiversity of marine ecosystems, making both more sensitive to additional stresses such as climate change." *Id.*
[277] *Id.*; Brander, *supra* note 265, at 19709–10.
[278] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, THE STATE OF WORLD FISHERIES AND AQUACULTURE 2010 22 (2010).

unclear how these new developments will ultimately affect the U.S. aquaculture sector because currently no aquaculture facilities are raising genetically modified fish for commercial sale.[279]

Another challenge the aquaculture industry will face is the growing incidence of spatial user conflicts. The FAO has recognized that "much of the coastline of the United States of America is well developed and competition for space in the coastal and near-shore environment creates user group conflicts."[280] Moreover, very few unallocated freshwater environments exist to support land-based operations.[281] These conflicts have made moving aquaculture operations into waters farther offshore into the U.S. EEZ an attractive alternative. However, there is a paucity of reliable data on the effects of aquaculture in deep-water environments, such as the EEZ,[282] making the viability of an offshore industry seem a far-off goal.[283]

The uncertainty faced by the industry in expanding its output is magnified by both the industry's potential to cause environmental degradation and the lack of a clear federal regulatory structure, as the private sector is justifiably nervous to develop fully an industry when it is uncertain of the future regulatory costs and liabilities.[284] The following section describes the

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[279] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN NORTH AMERICA: CANADA AND THE UNITED STATES OF AMERICA, FISHERIES AND AQUACULTURE CIRCULAR NO. 1061/2, 3 (2010).
[280] *Id.* at 2.
[281] *Id.*
[282] A Congressional Research Service Report notes that "[t]he present lack of knowledge — owing to limited experience, lack of research funding, and few studies focusing specifically on open ocean aquaculture — limits understanding of potential environmental concerns." HAROLD F. UPTON, CONGRESSIONAL RESEARCH SERV., OPEN OCEAN AQUACULTURE 11 (June 12, 2008). In particular, "little is known about the assimilative capacity of the marine environment for these pollutants," as, to date, "no countries have substantial offshore aquaculture industries with facilities sited in open-ocean environments." GAO, OFFSHORE MARINE AQUACULTURE: MULTIPLE ADMINISTRATIVE AND ENVIRONMENTAL ISSUES NEED TO BE ADDRESSED IN ESTABLISHING A U.S. REGULATORY FRAMEWORK 6 (2008); PEW OCEANS COMMISSION, *supra* note 232, at 6.
[283] Richard Langan, Dir. of U. of NH Atlantic Marine Aquaculture Ctr., Address at the NOAA 2007 National Marine Aquaculture Summit, 216-28 (June 27, 2007) (suggesting that open-ocean aquaculture is a fifty year project).
[284] *See generally, Concerning National Offshore Aquaculture Act of 2007 H.R. 2010, Hearing Before the Subcomm. on Fisheries, Wildlife & Oceans of the H. Natural Res. Comm.*, 110th Cong. (July 12, 2007) (statement of John R. MacMillan, Ph.D., President, National Aquaculture Ass'n); *see also* M. Richard DeVoe, *Marine Aquaculture Regulation in the United States: Environmental Policy and Management Issues*, 24 UNJR TECHNICAL REPORT 1–16.

inadequacy of the current regulatory structure for advancing a stable, sustainable aquaculture industry into the twenty first century.

B. Complexity and Inadequacy of Current Regulatory Framework

While the United States has made strides in regulating aquaculture over the last several decades,[285] the current regulatory framework is too complex and, ultimately, too lenient, to realize aquaculture's full potential and mitigate aquaculture's environmental problems in light of the challenges the industry will face in the coming century. Without cooperation and coordination among federal agencies,[286] perhaps achievable a single piece of federal legislation devoted to aquaculture development, aquaculture's role as the creator of polluting and exploitative tragedies of the commons will continue. Many federal agencies with very different missions and jurisdictional reaches govern aquaculture in disparate, often overlapping, and often inconsistent ways, including the Environmental Protection Agency ("EPA"), the FDA, NMFS/NOAA Fisheries, the FWS, the Army Corps of Engineers ("USACE"), and the United States Coast Guard. This Section briefly discusses each agency's role in aquaculture regulation.

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[285] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN NORTH AMERICA: CANADA AND THE UNITED STATES OF AMERICA, FISHERIES AND AQUACULTURE CIRCULAR NO. 1061/2, 73 (2010) ("In the last decade . . . the United States of America ha[s] made concerted efforts to improve aquaculture governance and increase financial support for R&D. These have included creation of national policies, strategic plans to support expansion, identification of priority goals and research topics, and efforts to establish national legislation addressing aquaculture. These efforts should improve regulation of the industry, balancing the needs to protect the environment, to sustain fisheries, and to enable a competitive industry to flourish.").

[286] The problem of overlapping and inconsistent regulatory jurisdiction is a current topic of debate, highlighted to the nation by President Barack Obama in his 2011 State of the Union Address:

> There are 12 different agencies that deal with exports. There are at least five different agencies that deal with housing policy. Then there's my favorite example: The Interior Department is in charge of salmon while they're in freshwater, but the Commerce Department handles them when they're in saltwater. I hear it gets even more complicated once they're smoked.

President Barack Obama, State of the Union Address (Jan. 25, 2011), in 157 CONG. REC. H461 (daily ed. Jan. 25 2011); *see also* Jody Freeman & Jim Rossi, *Agency Coordination in Shared Regulatory Space*, 125 HARV. L. REV. 1131, 1133 (2012).

However, this section is not intended to provide a complete list of regulatory jurisdiction over aquaculture operations; rather, it serves to demonstrate the complexity, uncertainty, and inadequacy characterizing the regulatory field in a select few areas of aquacultural impacts. A plethora of state laws and regulations pursuant to and independent of the federal laws delineated below also complicate the sphere of aquaculture regulation,[287] but are beyond the scope of this paper.[288]

The EPA has substantial regulatory authority over aquaculture facilities, with particular relevance to the tragedy of the commons by pollution. Discharges from many aquaculture facilities are subject to regulation under the EPA-administered federal Clean Water Act,[289] the purpose of which is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[290] The Clean Water Act provides that "[e]xcept as in compliance with this section and section[] . . . 402 of this Act, the discharge of any pollutant by any person shall be unlawful."[291] The term "discharge" means "any addition of any pollutant to navigable waters from any point source [and] any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source . . . ."[292] Section 402, in turn, provides that "the Administrator may, after opportunity for public hearing, issue a permit for the discharge of any pollutant," permits which have come to be known as National Pollutant Discharge Elimination System

[287] These include state laws on water quality, riparian landowner rights, zoning, marine spatial planning, public trust, and public health. For a particularly stringent example of state aquaculture regulation, see California's Sustainable Ocean's Act, S.B. 201 (2006).
[288] *See, e.g.*, ME. REV. STAT. tit. 12, §§ 6071–6673 (2011) (delineating Maine's detailed aquaculture laws which require permitting and monitoring and which ban certain activities).
[289] 33 U.S.C. §§ 1251–1387 (2006).
[290] 33 U.S.C. § 1251(a).
[291] *Id.* § 1311.
[292] *Id.* § 1362(12).

("NPDES") permits.[293] EPA has by regulation interpreted the Clean Water Act to apply to discharges into a concentrated aquatic animal production facilities ("CAAPF"), a point source under the Act, meaning that the limited number of aquaculture facilities that are large enough to fall within definition of a CAAPF will require a permit in order to discharge effluent.[294] However, these permits did not contain effluent limitation guidelines until 2004.[295] Since then, the largest CAAPFs, which produce more than 100,000 pounds of fish per year, have been subject to effluent limitation guidelines which contain requirements for reporting[296] and for the creation of "best management plans" which must reflect efforts to minimize the discharge of solids and feed accumulation below the pens using the best practicable technology.[297] However, these complex laws, many of which only apply to very large facilities and rely heavily on self-management, ultimately contain little more incentive to a facility to clean up its act than the natural incentive to reduce effluent discharges that would remain stagnant beside a net pen and contaminate the stock itself. However, in quick moving waters absent good faith compliance with effluent limitation guidelines the effects of their effluent on downstream users may still be salient.[298] EPA is also responsible for regulating land-based aquaculture waste disposal wells

[293] *Id.* § 1342; *see also* Nat'l Aquaculture Ass'n, Drugs Used in the US Aquaculture Industry, http://www.thenaa.net/downloads/Drugs_and_Chemicals_in_US_Aquaculture_11.10.pdf (last visited Mar. 10, 2012).
[294] 40 C.F.R. § 122.24(a) ("Concentrated aquatic animal production facilities . . . are point sources subject to the NPDES permit program."); *see also id.* § 123.25 (describing the rule applicable to State NPDES programs). Concentrated aquatic animal production facilities are defined as "a hatchery, fish farm, or other facility" meeting listed criteria or as designated on a case-by-case basis. *Id.* § 122.24(b), (c). CAAPFs include facilities that discharge fore more than 30 days per year and, in the case of cold-water fish, (1) produce more than 9,090 kg of fish or (2) deposit more than 2,272 kg of feed during the calendar month of maximum feeding. Criteria for Determining a Concentrated Aquatic Animal Production Facility, 40 C.F.R. part 122, app. C(a).
[295] Final Rule: Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, 69 FED. REG. 51892-01 (Aug. 23, 204) (codified at 40 C.F.R. part 451 (2011)); *see also* Janson Anderman-Hahn, *supra* note 232, at 1007.
[296] 40 C.F.R. § 451.3.
[297] *Id.* § 451.11.
[298] *See* GOLDBURG & TRIPLETT, *supra* note 187, AT 99, 141; Barrionuevo, *supra* note 187.

under the Safe Drinking Water Act[299] and the Resource Conservation and Recovery Act, which practicably have little regulatory power over aquaculture's impacts on aquatic or marine environments.[300]

The FDA's Center for Veterinary Medicine ("CVM") maintains regulatory authority over aquaculture operations under the Federal Food, Drug and Cosmetic Act[301] in several respects. First, the FDA regulates the use of antibiotics as drugs[302] through the New Animal Drug[303] Application Approval Process[304] approval process. The Secretary of the FDA *may* limit the use of animal drugs if they are found to pose a danger to public health.[305] In this process, CVM must *consider* the effects of the use of the drug in aquaculture facilities on the environment through an Environmental Assessment, and possible Environmental Impact Statement if the approval constitutes a "major federal action significantly affecting the quality of the human environment," under the National Environmental Policy Act ("NEPA"),[306] but NEPA requires no substantive action after collection of data into these reports.[307]

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[299] Safe Drinking Water Act, 42 U.S.C. §§ 300f to 300j-26 (2006).
[300] Resource Conservation and Recovery Act, 42 U.S.C. §§ 6901–6992k (2006); 40 C.F.R. § 146.5(e)(12). Detailed discussion of inland, indirect impacts of aquaculture are beyond the scope of this paper.
[301] 21 U.S.C. §§ 301 *et seq.* (2006).
[302] The term "drug" under the Act means an "article (other than food) intended to affect the structure or any function of the body of man or other animals." 21 U.S.C. § 321(g)(1)(C). The industry seems to understand that the term "drug" has a broad meaning. According to the National Aquaculture Association's website:

> Generally a drug is an article intended for use in diagnosis, cure, mitigation, treatment, or prevention of disease in man or other animals. It includes an article, other than food, that is intended to affect the structure or any function of the body of man or other animal, and includes articles that are intended for use as a component of a drug. For aquatic animal production, articles such as ice, oxygen and salt are, by definition, drugs.

Nat'l Aquaculture Ass'n, Drugs Used in the US Aquaculture Industry, http://www.thenaa.net/downloads/Drugs_and_Chemicals_in_US_Aquaculture_11.10.pdf (last visited Mar. 10, 2012).
[303] *Id.* § 360B.
[304] The process for application for uses of new animal drugs is set forth in section 360B(b) of the Act.
[305] *Id.* § 360B(a)(4)(B).
[306] 42 U.S.C. § 4321–4347 (2006).
[307] *Id.* § 4332.

Six drugs have been approved by the FDA for use in domestic aquaculture: Chorulon® (NADA 140-927), Finquel® (NADA 042-427), Tricaine-S (ANADA 200-226), Formalin-F® (NADA 137-687), Paracide-F® (NADA 140-831), Parasite-S® (NADA 140-989), Terramycin® (NADA 038-439), Romet-30® (NADA 125-933), and Sulfamerazine (NADA 033-950).[308] Also two antibiotics have been approved for limited use for specific food fish and specific diseases. These antimicrobials are oxytetracycline (Terramycin® for Fish; oxytetracycline monoalkyl trimethyl ammonium) and a potentiated sulfonamide (Romet-30®; ormetoprim: sulfadimethoxine).[309] According to the National Aquaculture Association, in aquaculture production, "[i]t is illegal to use antibiotics prophylactically to prevent aquatic animal disease or for production purposes such as to promote aquatic animal growth."[310]

The FDA also has investigative authority over aquaculture. Specifically, the Food and Drug Administration Amendments Act of 2007 direct the Secretary of the Department of Health and Human Services, in which FDA is situated, to submit to Congress a report that: "(1) describes the specifics of the aquaculture and seafood inspection program; (2) describes the feasibility of developing a traceability system for all catfish and seafood products, both domestic and imported, for the purpose of identifying the processing plant of origin of such products; and (3) provides for an assessment of the risks associated with particular contaminants and banned

[308] Nat'l Aquaculture Ass'n, Drugs Used in the US Aquaculture Industry, http://www.thenaa.net/downloads/Drugs_and_Chemicals_in_US_Aquaculture_11.10.pdf (last visited Mar. 10, 2012).
[309] *Id.*
[310] *Id.* This stance has also recently been adopted by the FDA with respect to antibiotic use in terrestrial livestock production. *See* U.S. Food and Drug Admin., FDA News Release: FDA Takes Steps to Protect Public Health (Apr. 11, 2012), *available at* http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm299802.htm. The FDA is accomplishing this task through issuance of three guidance documents, including a final guidance document entitled *The Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals*. *Id.* For news coverage of this decision, see Gardiner Harris, U.S. Tightens Rules on Antibiotics Use for Livestock, NY TIMES, Apr. 11, 2012, *available at* http://www.nytimes.com/2012/04/12/us/antibiotics-for-livestock-will-require-prescription-fda-says.html.

substances."[311] FDA has successfully completed this mandate, with its 2008 *Enhanced Aquaculture and Seafood Inspection — Report to Congress.*[312] The law also authorizes the Secretary to conduct heightened inspections of aquaculture facilities.[313] While these provisions have the potential to increase the transparency surrounding, and information about, aquaculture operations in U.S. waters, they are by design informational, rather than action-forcing. Aquaculture is, however, also subject to the Procedures for the Safe and Sanitary Processing and Importing of Fish and Fishery Products, also called the Seafood Hazard Analysis and Critical Control Point ("HACCP"),[314] a regulatory provision passed pursuant to the Federal Food, Drug and Cosmetic Act's definition of adulterated products.[315] These regulations require aquaculturalists and other fish providers to understand and manage risks associated with aquaculture production through adoption of sanitation control procedures and sanitation monitoring plans, requirements that are aimed to make aquaculture products healthful to consumers but that are not necessarily suited to the task of protecting aquatic and marine environments surrounding aquaculture facilities.[316]

The FDA also regulates genetically modified fish and has been working closely with Aquabounty, the company that created the AquAdvantage® salmon, to assess possible environmental and health consequences of the production and consumption of genetically modified fish. If it approves the AquAdvantage,® FDA will regulate the biotech salmon as a

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[311] 21 U.S.C. § 2105(c) (2006).
[312] *See* ANDREW C. VON ESCHENBACH, M.D., FOOD AND DRUG ADMIN., ENHANCED AQUACULTURE AND SEAFOOD INSPECTION - REPORT TO CONGRESS (2008), *available at* http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Seafood/SeafoodRegulatoryProgram/ucm150954.htm.
[313] 21 U.S.C. § 2015(b) ("The Secretary is authorized to enhance, as necessary, the inspection regime of the Food and Drug Administration for aquaculture and seafood, consistent with obligations of the United States under international agreements and United States law.").
[314] *See generally* 21 C.F.R. part 123.
[315] 21 U.S.C. § 402(a)(1), (a)(4).
[316] *See* 21 C.F.R. §§ 123.5 (requiring good manufacturing process), 123.6 (describing the HACCP plan requirements), 123.11 (requiring sanitation control procedures) (2011).

"new animal drug" subject to FDA's science-based review and approval. As explained by Lester M. Crawford, Deputy FDA Commissioner:

> [T]he FDA is authorized to exercise oversight of transgenic animals under the Federal Food, Drug and Cosmetic Act, which makes our agency responsible for the safety of drugs, and defines drugs as 'articles . . . intended to affect the structure or function of the body of man or other animals.' Because the genetic modification affects the structure and function of the salmon, and because it may produce a protein that is not generally recognized as safe for human consumption, the biotech salmon is, in the eyes of the law, a 'new animal drug,' and as such is subject to the FDA's science-based review and approval before it can be marketed. As part of this review, the FDA routinely considers evidence of a new animal drug's effect on, among other factors, animal health; disease susceptibility; zootonic potential; animal welfare; impact on domestic and wildlife populations; and the environment.[317]

Thus, FDA intends to regulate genetically modified fish under the Federal Food, Drug and Cosmetic Act as a "drug," which is defined as an "article (other than food) intended to affect the structure or any function of the body of man or other animals."[318] In sum, the FDA is deeply involved with modern aquaculture, and likely will become more intertwined with the success of the industry as aquaculture moves into the biotechnology market.

In the United States, the USDA governs freshwater aquaculture while NMFS/NOAA Fisheries, alongside the National Sea Grant Program, governs marine aquaculture.[319] The USDA actively funds and subsidizes aquaculture activities in its Farm Bills, having provided nearly four million dollars in grants in 2011.[320] USDA also sponsors substantial research and development

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[317] PETER BARTON HUTT, RICHARD A. MERRILL, & LEWIS A. GROSSMAN, FOOD AND DRUG LAW 1612 (quoting Lester M. Crawford, Deputy FDA Comm'r, FDA, at the American Enterprise Institute (June 12, 2003)).
[318] 21 U.S.C. § 321(g)(1)(C).
[319] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN NORTH AMERICA: CANADA AND THE UNITED STATES OF AMERICA, FISHERIES AND AQUACULTURE CIRCULAR NO. 1061/2, 75 (2010).
[320] Agriculture, Rural Development, Food and Drug Administration, and Related Agencies Appropriations Bill 2012, H.R. Rep. No. 112-__, at 15 (2012).

efforts.[321] Apart from subsidizing certain practices over others, though, the USDA does not actively manage potential environmental or public health harms. The National Sea Grant program, another agency within the Department of Commerce, also still actively funds aquaculture projects, with approximately three million dollars available to fund marine aquaculture research projects for fiscal year 2012.[322] Again, though, while this funding is aimed "to support the development of environmentally and economically sustainable ocean, coastal or Great Lakes aquaculture," it is not a regulatory mandate to aquaculture facilities, generally, to operate in a sustainable manner.

NMFS/NOAA Fisheries also regulates aquaculture activities pursuant to the Magnuson-Stevens Fishery Conservation Act ("Magnuson-Stevens").[323] Under Magnuson-Stevens, the term "fishing," which is defined to include the "harvesting" of fish and "any other activity which can reasonably be expected to result in the . . . harvesting of fish," has been interpreted to encompass aquaculture activities, thus giving NMFS/NOAA Fisheries jurisdiction over aquaculture activities under the Act.[324] Magnuson-Stevens, as amended by the Sustainable Fisheries Act in 1996, [325] requires NMFS/NOAA Fisheries to designate essential fish habitat ("EFH") for managed fisheries and implement conservation measures to protect those areas.[326] Thus, aquaculture operations in EFH areas are subject to conservation measures, though critics point out that NOAA has been inconsistent in its application of EFH conservation measures to

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[321] U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, CURRENT STATUS OF FEDERAL INVOLVEMENT IN U.S. AQUACULTURE, OTA-BP-ENV-170 (Sept. 1995).
[322] Oceanic and Atmospheric Research, National Oceanic and Atmospheric Administration, Dep't of Commerce, Announcement of Federal Funding Opportunity, NOAA-OAR-SG-2012-2003249 (2012).
[323] Magnuson-Stevens Fishery Conservation Act, 16 U.S.C. §§ 1801–1884 (2006).
[324] *Id.* § 1802(15); *see also* NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, MARINE AQUACULTURE POLICY 2 (June 2011) ("The statutory basis for NOAA's aquaculture activities includes the Magnuson-Stevens Fishery Conservation and Management Act . . . .").
[325] Pub. L. No. 104-297, 110 Stat. 3559 (1996) (codified at 16 U.S.C. §§ 1801-1883 (2000)).
[326] 16 U.S.C. § 1853(a)(7).

aquaculture facilities.[327] The eight Regional Fishery Management Councils have discretion to regulate aquaculture largely as they see fit under their regional management plans.[328] While some have chosen to do so, as demonstrated by the Gulf of Mexico Fishery Management Council's *Fishery Management Plan for Regulating Offshore Marine Aquaculture in the Gulf of Mexico*,[329] most others have abstained, and, consequently, aquaculture regulation by NMFS/NOAA Fisheries is limited on a national scale.

Moreover, NOAA recently adopted an aquaculture policy, an aspirational document that states broad policy guidelines for the agency's involvement with aquaculture, in June 2011. The admirable objectives stated in the policy include the goals to: "encourage and foster sustainable aquaculture development that provides domestic jobs, products, and services and that is in harmony with healthy, productive, and resilient marine ecosystems [and] compatible with other uses of the marine environment," "[e]nsure agency aquaculture decisions protect wild species and healthy, productive, and resilient coastal and ocean ecosystems, including the protecting of sensitive marine areas," and "[w]ork internationally to learn from aquaculture best practices around the world and encourage the adoption of science-based sustainable practices and systems."[330] Ultimately, though, this policy is just that: a policy. It contains no substantive or procedural requirements for the industry or regulators going forward. Thus, while NMFS/NOAA Fisheries exerts some authority over aquaculture, its practical effect on the industry's environmental record is likely limited.

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[327] *See, e.g.*, Erin R. Englebrecht, *Can Aquaculture Continue to Circumvent the Regulatory Net of the Magnuson-Stevens Fishery Conservation and Management Act?*, 51 EMORY L.J. 1187 (2002).
[328] See 16 U.S.C. § 1852.
[329] GULF OF MEXICO FISHERY MANAGEMENT COUNCIL, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, FISHERY MANAGEMENT PLAN FOR REGULATING OFFSHORE MARINE AQUACULTURE IN THE GULF OF MEXICO (2009).
[330] NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, MARINE AQUACULTURE POLICY 1–2 (June 2011).

NMFS/NOAA Fisheries may also regulate aquaculture, in concert with its inland counterpart FWS, when aquaculture impacts endangered or threatened species under the federal Endangered Species Act ("ESA"),[331] commonly thought of as the "pit bull"[332] of environmental law. Section 7 of the ESA directs that "[e]ach Federal agency shall, in consultation with and with the assistance of the Secretary [of Commerce or of Interior], insure that any action authorized, funded, or carried out by such agency . . . is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical] habitat of such species . . . ."[333] An agency can only avoid satisfaction of this duty under an Incidental Take Statement by complying with detailed procedural and substantive requirements, including completion of a Biological Opinion in consultation with NMFS/NOAA Fisheries or FWS, depending on where the species is found.[334]

Moreover, *any* aquaculture project, whether funded by a federal agency or not, is subject to the section 9 take prohibition, which provides that "it is unlawful for any person subject to the jurisdiction of the United States to . . . take any [endangered] species within the United States or the territorial sea of the United States [or] . . . take any such species upon the high seas . . . ."[335]

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[331] 16 U.S.C. §§ 1531–1544 (2006).
[332] See Michael J. Bean, *The Endangered Species Act and Private Land: Four Lessons Learned from the Past Quarter Century*, 28 ENVTL. L. REP. (ENVTL. LAW INST.) 10701, 10701 (1998).
[333] *Id.* § 1532(a)(2).
[334] *Id.* § 1532(b)(4).
[335] *Id.* § 1538(a)(B)–(C). While the law refers solely to endangered species, FWS regulations treat endangered and threatened species the same. 50 C.F.R § 17.31 (2011) ("Except as provided in subpart A . . . or in a permit . . . all of the provisions in § 17.21 shall apply to threatened wildlife . . . ."); 50 C.F.R. § 17.40–48. In contrast, the NMFS regulations for marine threatened species do not similarly replicate the ESA endangered species prohibitions. NMFS does not prohibit take of its threatened marine species unless there is a section 4(d) special rule applying the endangered species prohibitions to the threatened species at issue, meaning that some takes of species listed as threatened by NMFS may not require a permit. *See, e.g.*, 50 C.F.R. § 222.301(b); *cf.* 50 C.F.R. § 17.31(c) (requiring that if FWS issues a special rule, it must specify any prohibitions that apply).

This means that if an aquaculture operator actually "take[s]"[336] an inland aquatic or coastal marine endangered or threatened species, which can include habitat modification that actually injures a listed species, it will be subject to severe civil penalties under the ESA unless it completes the Incidental Take Permit and Habitat Conservation Plan processes to the satisfaction of NMFS/NOAA Fisheries or FWS.[337] The ESA has potential to have a large impact on the sustainability of aquaculture operations if facilities attempt to clean up their operations to avoid harming listed species. However, given that listed species are by definition hard to find, thus endangered or threatened, and that FWS and NMFS/NOAA Fisheries face substantial difficulties and costs in monitoring aquatic and marine environments to discover actual take of listed species, the deterrent effect of the ESA is likely limited.

Finally, the USACE and U.S. Coast Guard can exercise authority over aquaculture facilities in navigable waters. The Rivers and Harbors Act of 1899[338] provides that "it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty, or *other structures* in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States . . . except on plans recommended by the Chief of Engineers and authorized by the Secretary of the Army . . . ."[339] Moreover, the Act makes it unlawful "in any manner to alter or modify the course, location, condition, or capacity of, any . . . channel of

[336] 16 U.S.C. § 1538(a)(B)–(C). The statute defines a "take" to mean harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting listed species or attempting to engage in any such conduct. 16 U.S.C. § 1532(19). The FWS regulations interpret the term broadly, noting that "harm in the definition of 'take' in the [ESA] means an act which actually kills or injures wildlife. Such acts may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering." 50 C.F.R. §§ 17.3, 222 (2010). Similarly, the NMFS/NOAA Fisheries regulations define "harm in the definition of 'take' [to] mean[] an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including, breeding, spawning, rearing, migrating, feeding or sheltering." 50 C.F.R. § 222.102 (2010).
[337] 16 U.S.C. § 1539(a)(1)(B).
[338] 33 U.S.C. §§ 401, 403, 407 (2006).
[339] *Id.* § 403 (emphasis added).

any navigable water of the United States" without USACE authorization in a section 10 permit.[340] Similarly, the Coast Guard governs structure markings like lighting and signals to ensure safe passage of vessels past structures in waters of the United States.[341] These requirements are usually incorporated into USACE permits under section 10 of the Rivers and Harbors Act.[342] However, while these authorities may impact the siting of and markings on facilities and the agencies must still *consider* environmental impacts of permitting aquaculture operations under NEPA,[343] practically speaking they are unlikely to impact the sustainability of facilities' operation as the applicable laws contain no substantive environmental requirements.

Thus, despite the salient negative environmental effects the modern aquaculture industry has had, the United States lacks a strong national aquaculture policy and supporting federal presence.[344] The current patchwork regulatory structure is ineffectual at preventing the tragedies of the commons that have arisen by aquaculture's pollution and exploitation of inland aquatic and coastal marine environments. While attempts have been made to address the problems aquaculture has begun to cause, to aid the industry in realizing its full potential as a solution to a tragedy of the commons, these attempts have not been strong enough to guide the industry onto a sustainable path.

Industry is not the only group with a responsibility here, as indicated in the National Aquaculture Act of 1980.[345] Rather, the United States, which has played a large role in subsidizing and encouraging development of aquaculture throughout the industry's history, has a

[340] *Id.*
[341] *See* 43 U.S.C. § 1333(e); 14 U.S.C. §§ 81–87; 33 C.F.R. §§ 64–67.
[342] *See* Kristen M. Fletcher, *Law & Offshore Aquaculture: A True Hurdle or A Speed Bump?, in* EFFORTS TO DEVELOP A RESPONSIBLE OFFSHORE AQUACULTURE INDUSTRY IN THE GULF OF MEXICO: A COMPENDIUM OF OFFSHORE AQUACULTURE CONSORTIUM RESEARCH 23 (Bridger, C.J. ed. 2004).
[343] 42 U.S.C. § 4332.
[344] U.S. CONGRESS, OFFICE OF TECHNOLOGY ASSESSMENT, CURRENT STATUS OF FEDERAL INVOLVEMENT IN U.S. AQUACULTURE, OTA-BP-ENV-170 (Sept. 1995).
[345] National Aquaculture Act of 1980, H.R. Rep. No. 96-196(II) 7/2907 (July 16, 1979).

duty to ensure that the industry does not come to be characterized by tragedies of pollution and exploitation like the tragedy well underway in the context of wild capture fisheries. The U.S. government must instead condition its support on, or plainly mandate, environmentally and socially responsible industry behavior. The World Bank explained the dilemma well: "[t]he vision of sustainable aquaculture demands not only a favorable business climate, but also a governance framework that embraces social objectives and enforces environmental standards."[346] Furthermore, it has become clear that the success of aquaculture in the coming years will also depend on the extent to which coastal areas are polluted by other causes, like inland nonpoint source pollution.[347] Thus, state and federal regulators must also regulate sources of coastal pollution to give adequate support to a sustainable aquaculture industry.

Luckily, the rapid development of technology accompanying the "blue revolution"[348] has ensured that sustainable aquaculture production is available and feasible. For example, in addition to the possibility of moving offshore to dilute coastal pollution, researchers have developed closed systems that require minimal disease and pest control and produce virtually no pollution.[349] Aquaculturalists are also perfecting integrated systems, also called polyculture systems that combine culture of fish aquaculture with culture of mollusks or seaweed so "the wastes from one organism are used as inputs to another, resulting in the optimal use of resources and less pollution overall."[350] These systems have the potential to be both more environmentally sound

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[346] THE WORLD BANK, *supra* note 4, at 2.
[347] Robin Kundis Craig, *The Other Side of Sustainable Aquaculture: Mariculture and Nonpoint Source Pollution*, 9 WASH. U. J.L. & POL'Y 163, 164 (2002).
[348] *See supra* note 203, AT 1–2 (defining the "blue revolution" as "a period of broad advances in culture methods and associated increases in production").
[349] ECOPLAN INTERNATIONAL, INC., GLOBAL ASSESSMENT OF CLOSED SYSTEM AQUACULTURE, PREPARED FOR THE DAVID SUZUKI FOUNDATION & THE GEORGIA STRAIT ALLIANCE (2008).
[350] *See, e.g.,* HALWEIL, *supra* note 227, at 7, 9, 23; UPTON & BUCK, *supra* note 203, at 10 (presented the integrated aquaculture approach implemented at the University of New Hampshire as a model for open ocean aquaculture); WHITE, O'NEILL, AND TZANKOVA, *supra* note 4, at 9, 13.

operations and more economically efficient.[351] Moreover, the use of fishmeal in aquaculture feed can be reduced and researchers are using developing more sustainable plant-based feeds for use on fish farms.[352] Thus, the technology exists to guide aquaculture onto a sustainable path.

Aquaculture's recent boom and the rapid technological development have made it the obvious choice going forward for satisfying the world's growing appetite for protein.[353] It is a choice that has potential to be more sustainable, as an alternative to exploitative overfishing and as a lower-impact source of protein than many industrially raised terrestrial livestock, if done correctly.[354] But we have a long way to go. As stated by James Connaughton, former Chairman of the White House Council on Environmental Quality,

> Now is the time, not to have a national conversation about aquaculture, now is the time to have a national system of sound management of aquaculture to provide the certainty that's necessary to do it right, to assure that we have the ecological integrity to the process [sic], and, again, to set a beacon for the world.[355]

Without institution of "[m]utual coercion mutually agreed upon," the United States aquaculture industry is causing, rather than solving, tragedies of the commons.[356]

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[351] WHITE, O'NEILL, AND TZANKOVA, *supra* note 4, at 9 ("Polyculture systems can provide mutual benefits to the organisms reared by creating symbiotic relationships while allowing for a balanced use of the available aquatic resources, whereas intensive monoculture systems extract resources from the system and place more stress on the surrounding environment. In addition, integrated systems can increase the economic efficiency of fish farms through improved conversion rates of input materials.").
[352] *Id.* at 13.
[353] *See* NOAA, AQUACULTURE PROGRAM FACTSHEET (Mar. 2010) *available at* http://aquaculture.noaa.gov/pdf/aq_factsheet_march2010.pdf.
[354] *See,* HALWEIL, *supra* note 227, at 19, 21 (2008); *see also* Anderman-Hahn, *supra* note 232, at 1043 (cautioning that we must ensure that aquaculture is not "destined to repeat the problems associated with industrial agriculture and cause environmental disaster" and that "[i]t is therefore necessary that a comprehensive management plan be adopted now"). However, without adequate mutual coercion, aquaculture seems to be "following the same trajectory as land-based agriculture, but over a dramatically shorter timespan." Halweil, *supra* note 227, at 13; *see also* UPTON & BUCK, *supra* note 203; GOV'T ACCOUNTABILITY OFFICE, GAO-08-594, OFFSHORE MARINE AQUACULTURE: MULTIPLE ADMINISTRATIVE AND ENVIRONMENTAL ISSUES NEED TO BE ADDRESSED IN ESTABLISHING A U.S. REGULATORY FRAMEWORK (May 2008).
[355] James Connaughton, Chairman, White House Council on Envtl. Quality, Address at the NOAA 2007 National Marine Aquaculture Summit, 136 (June 27, 2007) *available at* http://aquaculture2007.noaa.gov/pdf/transcript62707.pdf.
[356] Hardin, *supra* note 9, at 1247.

VI. Conclusion

While this Paper recognizes that it would be unreasonable to envision sustainable aquaculture as a no-impact alternative to other aquatic and terrestrial food sources,[357] it is certainly reasonable to hold aquaculture to its potential to be minimally impactful relative to other protein sources. While historically the United States envisioned aquaculture as a solution to the exploitation tragedy of the commons, and not as a contributor to the pollution tragedy, the United States still has the potential to farm fish in a manner that maintains its status as a net solution to the problems of our global commons. However, the United States can ensure that the aquaculture industry is not "destined to repeat the problems associated with industrial agriculture [or industrial fishing] and cause environmental disaster . . . ."[358] The first step is acknowledging the problem, grounding aquaculture's mistakes in history, and learning from history to craft a solution that solves the current problem without creating additional strains on the local, national, or global commons. With carefully crafted, clear, and streamlined regulatory requirements, the U.S. aquaculture industry can become a "green" blue revolution and realize its full, impressive potential.

[357] It would be an "unreasonable evidentiary standard [to require that a] particular facility [prove] no impact…in the face of international and other sources of competition." Richard Smith, Partner, Robinson & Cole, L.L.P. Address at the NOAA 2007 National Marine Aquaculture Summit, 103 (June 27, 2007) *available at* http://aquaculture2007.noaa.gov/pdf/transcript62707.pdf.
[358] Anderman-Hahn, *supra* note 232, at 1043.